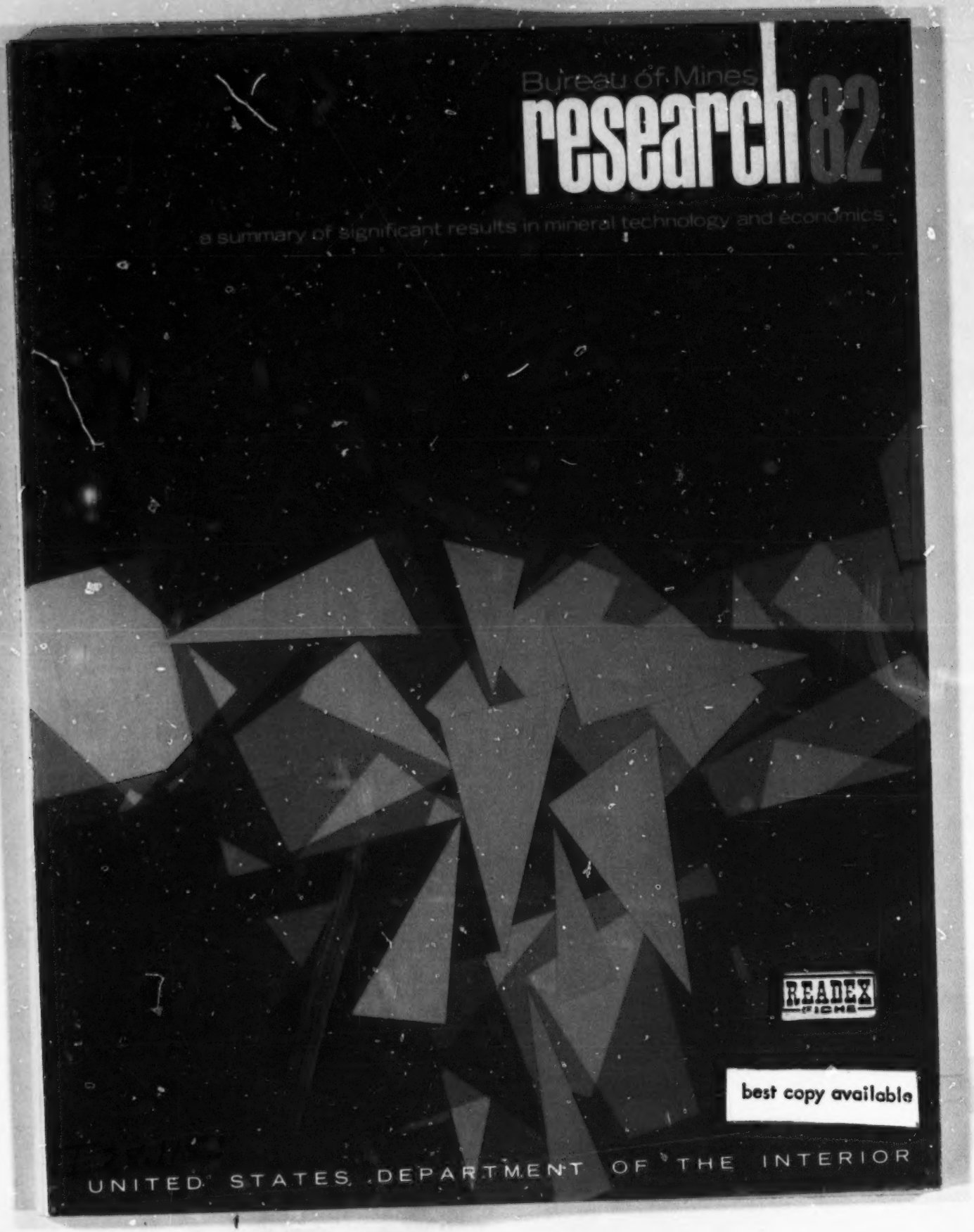

Bureau of Mines
research 82
a summary of significant results in mineral technology and economics
UNITED STATES DEPARTMENT OF THE INTERIOR

READEX MICRO
best copy available

Bureau of Mines Research 1982

a summary of significant results in mineral technology and economics

NEWARK PUBLIC LIBRARY

DEC 29 1982

U. S. GOVT. PUBS.
DEPOSITORY 376

By Staff, Bureau of Mines

Compiled and edited by
Jerald R. Pederson

UNITED STATES DEPARTMENT OF THE INTERIOR
James G. Watt, Secretary

BUREAU OF MINES
Robert C. Horton, Director

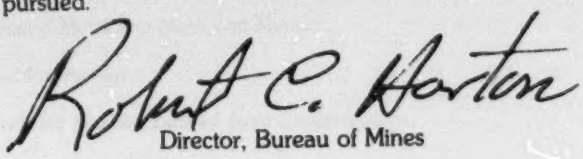
For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Foreword

Minerals, and the adequacy of America's mineral supply, are subjects of growing national concern in the 1980's. They have been subjects of concern to the Bureau of Mines for most of this century.

The Bureau's mission is to help assure an adequate and dependable flow of minerals at reasonable costs. That mission is pursued through the acquisition and analysis of minerals data on a worldwide basis, and through research to make mining and mineral processing safer, more productive, and more compatible with the effective use of all the Nation's resources.

Research 82 is the 12th annual summary of significant developments in Bureau programs. It reflects both the scope of the Bureau's mission, and the success with which that mission is being pursued.



Director, Bureau of Mines

Contents

	Page
Foreword	i
Introduction	1
Mining Research	3
Conservation and Development	4
Mining Technology	4
Packer Tests for Leak Detection in In Situ Mining Wells	4
Determining Leachant and Ore Body Compatibility for Uranium In Situ Mining	4
Use of Clay Stabilizers To Prevent Permeability Losses	6
High-Angle Conveyor	6
Compact Service Hoist for Underground Metal and Nonmetal Mines	7
Design Criteria for Shaft Support	8
Improved Skip Designs for Increased Production	9
Resource Conservation Technology	10
Development of Geophysical Methods for Measurement of Joint Characteristics	10
Predicting Mine Water Inflow	11
Blast Design To Minimize Airblast and Ground Vibration	12
Fatigue Effects of Repeated Blasting	13
Blasting Effects on Water Wells in Appalachia	13
Acid Mine Drainage Prevention—Use of Surfactants	14
A Fracture Dewatering Strategy for Underground Coal Mines	15
Removing Heavy Metal From Copper-Nickel Stockpile Runoff	16
Use of Cemented Backfill To Prevent Subsidence Damage and Increase Production	17
Development of Slurry Backfill for Oil Shale Mining	17
Controlled Burnout of Underground Coal or Waste Bank Fires	18
Computer Modeling of Surface Coal Mining Effects on Ground Water in the Powder River Basin	20
Inventory of Metal and Nonmetal Waste Disposal Sites	21
Development of Metal-Nonmetal Waste Disposal Design Guide	21
Disposal of Mill Tailings in a Surface Backfill	22
Scraper Wheel Slip Monitor	23
Enhancing Short- and Long-Range Availability of Nitrogen and Phosphorus on Topsoil-Deficient Mine Spoil	24
Ecological Studies on the Revegetation Process of Surface Coal Mined Areas in North Dakota	25
Soil Depth Requirements for Surface Mine Reclamation in the Northern Great Plains	26
Health and Safety Technology	27
Respirable Dust	27
Improved Sampling Techniques Aid Dust Control Research	27
New Approaches for Personal Dust Exposure Monitoring	28
Conveyor Belt Dust Control	29
Improved Water Spray System for Continuous Miner Dust Control	30
Advances in Longwall Dust Control	30
Radiation Hazards	31
Improved Continuous Working Level Monitoring System	31
Computerized Radiation Monitoring and Control System	32
Noise Control	33
Retrofit Noise Control Techniques for the Crushing and Screening of Nonmetallic Minerals	33
Integration of Noise Control Technology Into Load-Haul-Dump Machines	34
Computer Modeling of Nonmetallic Screen Deck Performance	34
Industrial Hygiene	35
Diesel Engine Emission Control by Fuel Modification	35
Monitoring Mine Air Pollutants	37
Products of Thermal Degradation of Mine Materials	37

Page

Ventilation 37
Water Spray Cooler 37
Fire and Explosion Prevention 38
Anti-Incendive Coal Cutting Bits 38
Machine-Mounted Water Sprays for Preventing Frictional Ignition at the Mine Face 39
Protection of Conveyor Belt Haulageways Against Dust Explosions 39
Dust Suppression at Belt Conveyor Transfer Points To Reduce Dust Explosion and Health Hazards 40
Application of an Inerting Technique To Combat Deep Mine Fires 42
Portable Coal Mine Dust Incombustible Meter 43
Methane Control 43
Methane Emissions From an Advancing Face in a Domal Salt Mine 43
Wireless Real-Time Survey Tool 44
Explosives 45
Sheathed Permissible Explosive Charge for Unconfined Shooting 45
Safety Procedures for Guarding Blast Affected Areas 46
Test Development and Verification in Support of Department of Transportation and United Nations Classification of Explosives 46
Postdisaster Survival and Rescue 47
Compressed Oxygen Self-Rescuer 47
Automated Breathing Metabolic Simulator 47
Mine Personnel Locator and In-Mine Activity Controller 48
Systems Engineering 49
Research Results at Lake Lynn Laboratory 49
Statistical Mine Accident Analysis 50
Ground Control 50
Surface Evaluation of the 4M Miniminer System 50
Automated Temporary Roof Support for Single, Fixed-Head Roof Drills—An Update 51
Remote-Controlled Bolter for Metal-Nonmetal Mines 52
Epoxy Cartridges for Roof Bolts 52
Uniform Roof Bolt Tension 53
Roof Bolt Bond Tester 54
Anchorage of Inundation Bulkheads in Coal Mine Openings 56
Synthetic Radar for Coal Mine Hazard Detection 56
Closure-Rate Instruments for Roof Fall Prediction 57
Longwall Mining Design Parameters 58
Industrial Hazards 58
Intrinsically Safe Monitoring System 58
Improved Personal Lighting System—Advances in the Miner's Cap Lamp 60
Defining Illumination Requirements for Underground Metal and Nonmetal Mines 61
Whole-Mine, Medium Frequency Communications 61
Fiber Optic Technology in Underground Mines 62
Explosionproof Enclosure Research 63
Formalizing Occupational Training 64
Formalizing Health and Safety Training 64
Slack and Overload Rope Protection System for Mine Hoists 65
Analytical Investigation of Deep Shaft Wire Rope 66
Minerals and Materials Research 67
Extractive Metallurgy 69
High-Temperature Thermodynamics and Kinetics 69
Particulate Mineralogy 69
Chemical and Physical Enhancement of Domestic Chromites 70
Appraisal of Critical Minerals From Northwestern and Alaskan Resources 71
Lead Production by Hydrometallurgy and Molten-Salt Electrolysis 73
Titanium Recovery From Domestic Perovskite Ores 74
Tungsten Recovery From Searles Lake Brines 74
Alternate Fuels for Mineral and Metallurgical Processes 74

	Page
Materials and Recycling Technology	76
Use of Sulfur Concrete	76
Substitutes for Refractory-Grade Bauxite	77
Substitutes for Chromium in Alloy Steels	78
Vapor Phase Preparation of Titanium Alloy Powder	79
Refractories for Severe Service Conditions	79
Basic and Applied Corrosion Studies	79
Rapid Identification of Scrap Metals	81
Utilization of Wastes Containing Zinc for Electrogalvanizing	82
Byproduct Mineral Recovery From Phosphate Wastes	84
Metal Recovery From Secondary Copper Smelter Flue Dusts	84
Rare Earth-Cobalt Permanent Magnets	85
Improved Titanium Components Through Innovative Processing Technology	85
Foundry Charge Materials Chemistry	86
Fundamentals of Flocculation	87
Mineral Data Analysis	89
Field Assessment and Evaluation	90
Mineral Resource Evaluation of Wilderness Lands	90
Mineral Resource Evaluation of Tribal Lands	91
Minerals Availability	92
Aluminum Availability—Market Economy Countries: A Minerals Availability System Appraisal	92
Copper Availability—Market Economy Countries: A Minerals Availability System Appraisal	92
Platinum Availability—Market Economy Countries: A Minerals Availability System Appraisal	93
The Depletion Allowance and Domestic Minerals Availability—A Case Study in Copper	93
Minerals Policy and Analysis	94
SIC-Based Demand Information System for Nonfuel Minerals	94
An Input-Output Analysis: The Impact of a Defense Buildup on the Mineral Industries	94
Technological Innovation in the Copper Industry	94
Minerals Information	95
Automated Minerals Information System	96
Minerals Data Source Directory	96
Supply-Demand Projection for Steel Mill and Foundry Products	96
Helium Operations	99
Helium Activities	100
Directory	102
Recent Publications and Patents	104

Introduction

Research 82 highlights significant studies conducted during the past fiscal year at Bureau facilities and offices. Readers who want more information about the projects and studies summarized here can contact the researchers whose names and locations appear with each summary. General information on Bureau of Mines programs is available from the Office of Technical Information, 2401 E Street, NW., Washington, D.C. 20241.

A listing of principal officials, a location map of field facilities, and a selected bibliography of publications and patents issued on Bureau developments during the past 3 years are provided.

The Mission

The Bureau of Mines has principal responsibility for conducting research and for collecting, interpreting, and analyzing information involving mineral reserves and the production, consumption, and recycling of mineral materials. It does so to help assure the Nation, at low human, social, and environmental cost, the mineral supplies necessary to maintain national security, employment, and continued economic growth; and to help stimulate the private sector in the production of minerals so that an appropriate and substantial share of national needs can be supplied from domestic sources.

Towards these objectives the Bureau of Mines—

- Collects and interprets information on minerals, the mineral industries, and sources of minerals throughout the world.
- Identifies and analyzes problems relative to the Nation's minerals requirements.
- Formulates policy options and recommendations to meet these needs, thus providing a sound basis for minerals policy formulation and direction for Bureau programs.
- Seeks to provide technological advances to improve efficiency and recovery from mineral deposits and processing systems, to reduce undesirable environmental effects, and to improve health and safety, economic, and national security aspects of producing, using, reusing, and disposing of mineral materials.
- Produces, purchases, stores, and sells helium for the U.S. Government.

Organization and Functions

The Bureau of Mines is headquartered in Washington, D.C., with centers, laboratories, and supportive offices located throughout the United States.

The Director is the Chief Executive Officer of the Bureau. He is assisted by a Deputy Director, an Assistant Director Planning and Budget, and a Senior Staff. The programs of the Bureau are carried out by five line Assistant Directors. The program functions are as follows.

Mining Research

Research and development programs aimed at improving the technology for extracting minerals from the ground. Goals are:

To reduce health and safety hazards in mining;

To increase efficiency, productivity, and the percentage of mineral recovery; and

To overcome adverse environmental effects caused by mining and mining wastes. Supported by two headquarters divisions and four research centers in the field.

Minerals and Materials Research

Research and development programs aimed at improving technology for processing and using minerals and mineral products; and disposing of mineral wastes. Goals are:

To increase efficiency and economy in the techniques used to extract metals and other mineral products from their ores and process them into usable raw materials;

To improve mineral material performance, and critical and strategic material substitutes; and

To overcome adverse environmental effects stemming from the production and disposal of mineral-based substances. Supported by two headquarters divisions and six research centers and one engineering laboratory in the field.

Mineral Data Analysis

Responsible for:

Analyses to determine how the policies and actions of governments relate to the international flow of minerals, and how supply, demand, and technology relate to the national and world economy;

Engineering and related investigations to assess mineral potential of public lands;

Assessment of impacts of proposed government projects on mineral resources and mining;

Providing a point of contact, advice, and assistance on mineral matters to State and local governments; and

Investigations and evaluations of mineral deposits and industry operations to evaluate economic-engineering aspects of mineral resource availability. Supported by two headquarters divisions, a State Liaison Office, and four field operations centers.

Minerals Information

Responsible for:

Gathering, evaluating, and reporting statistical, economic, and related information on minerals; and

Continuing surveillance and evaluation of all government, commercial, industrial, and consumer activities in and related to the minerals industries at home and abroad. Supported by five headquarters divisions.

Helium Operations

Responsible for the Federal Helium Program, including helium production, storage, conservation, and sales activities. Supported by a small headquarters staff and a General Manager—Field Operations in charge of helium plants and facilities in the field.

Mining Research

Research and development activities were conducted at field facilities in:

Denver, Colo.,

Pittsburgh, Pa.,

Spokane, Wash.,

and Twin Cities, Minn.

Mining Technology

Packer Tests for Leak Detection in In Situ Mining Wells

Daryl R. Tweeton, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

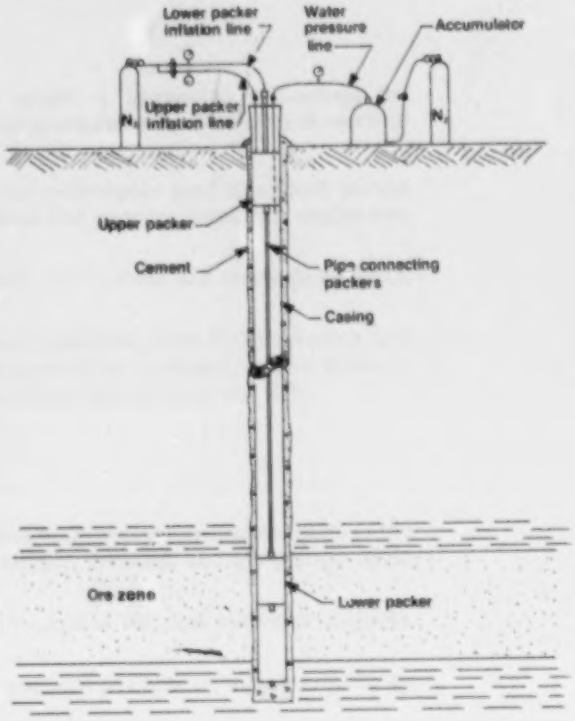
For economic and environmental reasons, in situ leaching operations must be sure that recovery and injection wells do not leak. Significant loss of solution could threaten the economic viability of the operation, and leaching companies are required by regulatory agencies to provide evidence that their wells do not leak. For example, Wyoming requirements for well integrity specify that the well must maintain pressure within 5 pct of the maximum planned leach solution injection pressure for 10 min.

Wells are tested by sealing them with packers, pressurizing them, and then monitoring the pressure drop. Operators have experienced difficulties with commercially available packers, most of which were designed to be used in steel-cased wells rather than the fiberglass- or plastic-cased wells used for in situ mining. The packers often leak, and at best are cumbersome and expensive. The Bureau designed and constructed prototype packers suitable for leaching wells. After successful laboratory tests, the packers were field tested at an in situ uranium mining operation in Wyoming.

Wells can be tested either with one packer near the top or with two packers. The single packer test is easier, but cannot distinguish between leaks in the zone to be perforated and those above that zone. All of the 32 wells at the field site were tested. The wells were first tested with a single packer set near the top of the casing and inflated to 300 psi (pounds per square inch) with nitrogen. The water in the well was pressurized to 200 psi by using nitrogen to pressurize water in an accumulator connected to the water pressure line.

The well was then shut in, and the pressure drop monitored to determine if the well met the integrity specifications. Wells that failed this single packer test were tested with the double packer system with the lower packer set at the proposed perforation level. These tests showed that most of the leaks were due to a poor cement seal near the bottom, in the zone to be perforated, so the wells could be used.

In the remaining leaky wells, the location of the leak in the casing was found by raising the lower packer and repeating the pressure test at 10-ft intervals. All of the remaining leaks were within 20 ft of the surface. The casings were subsequently repaired and successfully tested again with the single packer system.



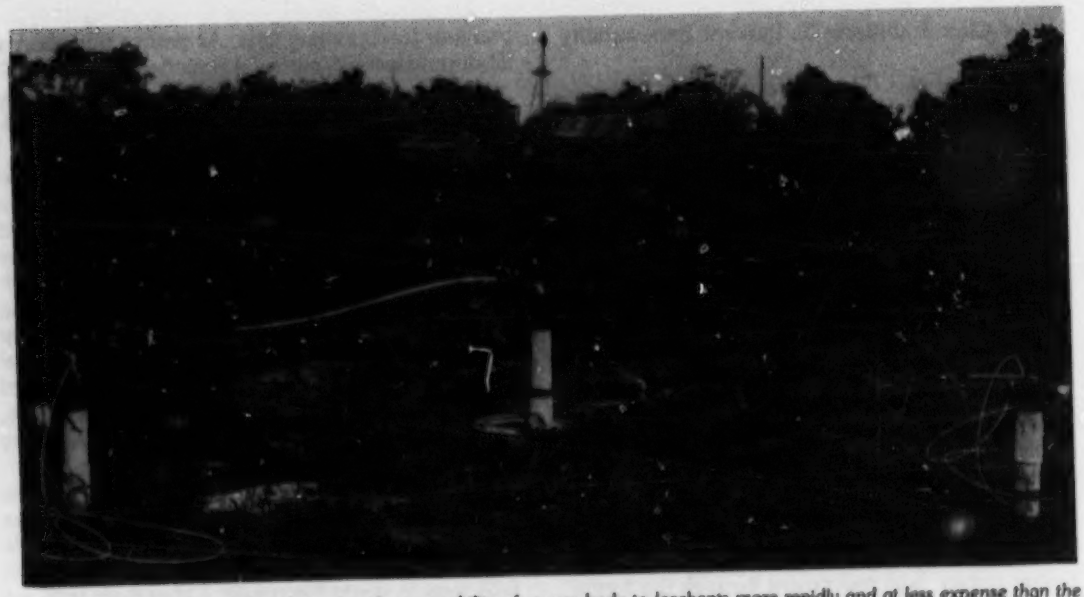
In situ leaching recovery and injection wells can be tested for leaks by single or double packers.

These initial tests showed that the packer system functioned reliably under repeated field use. The leaching company was very satisfied with the performance of the packers, and considered them to be a significant improvement over the packers they had used previously. Some modifications will be made to simplify using the packers, but overall, the field test was very successful.

Determining Leachant and Ore Body Compatibility for Uranium In Situ Mining

Daryl R. Tweeton, Technical Project Officer
Twin Cities Research Center, Minneapolis, Minn.

The uranium in situ mining industry needs leachants (leach solutions) that are more compatible with current environmental regulations than the



A three-well test can be used to determine the amenability of an ore body to leachants more rapidly and at less expense than the common five-spot configuration. Small-diameter sampling wells are drilled to form a right angle with the injection-production well (center). Water samples are drawn from the sampling wells by nitrogen pressure in a sampling tube—no pump is required.

ammonium carbonate-bicarbonate leachants used now. Ammonium levels cannot be lowered sufficiently to satisfy regulations concerning restoration of ground water quality following leaching with ammonium carbonate-bicarbonate. The industry must also be able to determine the amenability of an ore body to the more environmentally compatible leachants.

Two leachants that would meet industry needs are potassium carbonate-bicarbonate and sodium carbonate-bicarbonate. Potassium carbonate-bicarbonate has not been used because of its high cost; however, a technique developed by the Bureau—flushing the ore body with potassium chloride before leaching—reduces the chemical cost by supplying cation echange sites with potassium from the relatively cheap potassium chloride. Sodium carbonate-bicarbonate is inexpensive, but can cause losses in permeability owing to plugging caused by swelling clays.

Recent research by the Bureau has focused on developing a relatively inexpensive and rapid field test to determine the amenability of an ore body to the particular leachant. The test developed is a modification of the push-pull test, wherein the leachant is injected and later produced from the same well. The key modification is the addition of two sampling wells forming a right angle with the injection-production well. Water samples are drawn from the sampling wells by nitrogen pressure in a sampling tube. No pump is required in the sampling wells, so they can be of small diameter and hence relatively inexpensive.

The well cost for this three-well test is only half that of the well cost for the more common five-spot configuration. The three-well test can be completed in 3 weeks, whereas the five-spot test requires at least 6 months. The disadvantage of the three-well test is that the close spacing requires the wells to be drilled quite straight and there is a greater tendency toward channelization between wells.

The three-well test will not replace the five-spot test, but provides a relatively rapid and inexpensive intermediate step between laboratory results and larger field tests to help ensure that the larger tests will succeed. The Bureau has determined the conditions under which the test will yield meaningful results of important ore body parameters, such as rate of leaching and anisotropy in permeability. These conditions involve flow rate, well spacing, and the length of time between injection and production. They must be satisfied if the test is to provide the maximum amount of useful information.

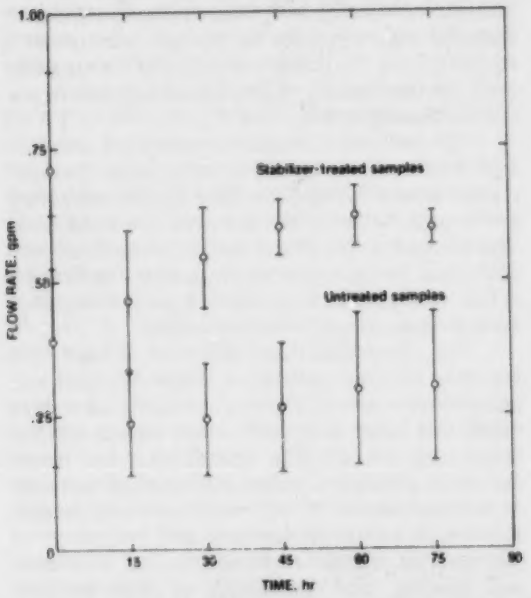
Use of Clay Stabilizers To Prevent Permeability Losses

Kenneth E. Hjelmstad, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

The most widely used in situ leach mining technique is to inject leach solutions down injection wells and to withdraw the metal-laden solution from adjacent recovery wells. An unfortunate side effect in sandstone deposits containing clay is the disruption of the clay-water chemical equilibrium. The solution may cause swelling or migration of indigenous clays. Clay swelling plugs voids in the sandstone immediately adjacent to the injection well. The injection of leach solution also frequently causes clay platelets to disintegrate into negatively charged fine particles that repel one another and disperse in the leaching solution through the formation until decreases in fluid velocity or constrictions in the flow paths cause the particles to drop out of the solution. As these particles build up at some distance from the injection well, they further reduce fluid movement through the formation. This loss of permeability through the formation severely affects leach mining efficiency and economics.

The Bureau is attempting to solve the problem of permeability loss in clay-bearing sands at uranium leach mining sites. As part of this effort a laboratory test program was undertaken to evaluate a commercially available hydrocarbon polymer clay stabilizer to determine if it could prevent permeability loss. A large test cell containing a simulated injection well with casing and well screens designed to model the high-fluid-velocity region around an injection well was used for the test program. Fluid flow tests indicated that twice the flow rate could be maintained through the test sand by treating it with the organic polymer clay stabilizer. Clay swelling tests indicated that the polymer prevented breakup and volume increase of the clay. Zeta potential measurements made on fine clay particles showed that the clay stabilizer was strongly electropositive, which reduced the negative charge on the fine clay particles and hence their dispersive forces.

Since these laboratory tests indicated that clay stabilizers successfully prevented permeability loss in a clay-bearing test sand, efforts are being made to find a leaching operator willing to participate in field tests to verify the results. Laboratory tests are continuing to assess the range of leaching conditions for which clay stabilizers would be beneficial.



Laboratory tests have shown that clay stabilizers can prevent permeability losses in clay-bearing sands by preventing the breakup and volume increase of clay caused by leach solutions.

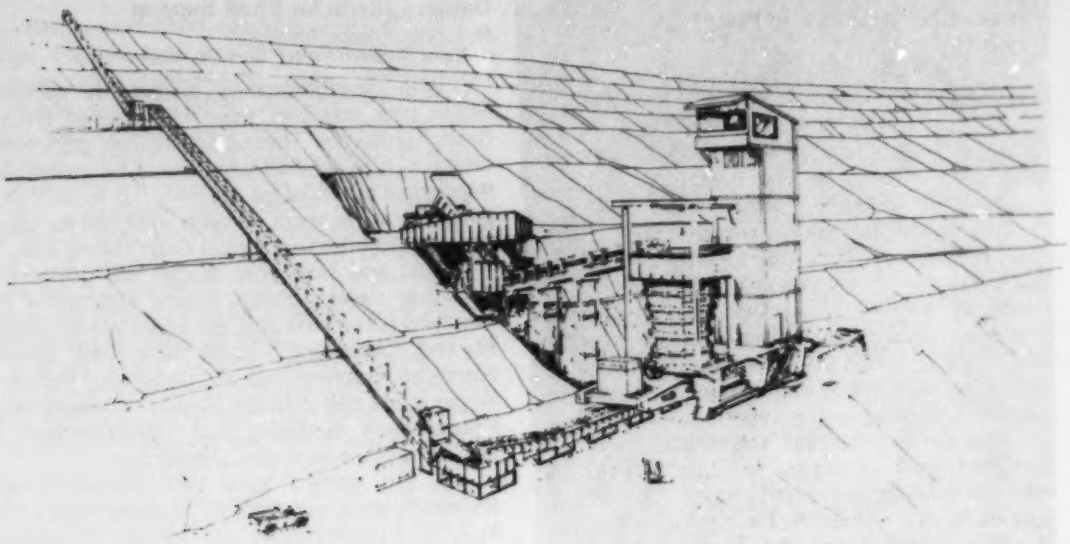
High-Angle Conveyor

E. M. Frizzell, Technical Project Officer
Spokane Research Center, Spokane, Wash.

As part of its research to develop more efficient methods for moving ore and waste rock out of open pits, the Bureau recently completed an evaluation of the applicability and feasibility of high-angle conveying. From discussions with mine personnel and analysis of the requirements of various copper, taconite, and phosphate open pit mines, it was concluded that a high-angle conveyor should meet the following performance criteria: a conveying angle up to 45°, lump size of minus 8 in, tonnage rate of 3,500 tph (tons per hour), and a lift of 320 ft.

A detailed examination was made of different high-angle conveying concepts including bucket ladders, belt with partitions, sandwich belts, screw conveyors, and other existing manufacturers' equipment. Evaluation of the concepts showed that a sandwich belt conveyor would best meet the requirements of a high-angle conveyor. Additional investigation into the history and theory of sandwich belt conveyor systems resulted in preliminary design of a pneumatically pressed sandwich belt conveyor.

The high-angle conveyor concept, combined with a mobile in-pit crusher, was incorporated into



The concept of using a high-angle conveyor as a more efficient method for moving ore and waste rock out of open pits was evaluated and shown to be economically attractive.

hypothetical mine plans for copper, taconite, and Western U.S. phosphate open pit mines. The haulage and crushing costs of the high-angle conveying system were compared with those of conventional truck haulage and crushing to determine which system is economically more attractive. The results show that in the 10- to 15-pct range of return on investment after taxes, the high-angle conveyor system would be more economical than conventional truck haulage in the copper, taconite, and phosphate mines.

Compact Service Hoist for Underground Metal and Nonmetal Mines

A. E. Gooch, Technical Project Officer
Spokane Research Center, Spokane, Wash.

Improved methods for the vertical transport of personnel and supplies to and from stopes in underground vein mines are needed to improve mining efficiency and productivity. Specifically, a need for small, lightweight, relatively low-cost, in-mine service hoists has been identified by the American Mining Congress Technical Advisory Committee, by mine personnel, and by previous Bureau studies on ways to improve productivity in underground mines.

In response to this need, a compact hoist system has been developed by the Bureau. The hoist consists of three distinct components—frame, cage, and drive unit. The drive, or traction unit, climbs two ⅜-in stationary wire ropes; therefore, it is not restricted to straight "line of sight" openings. The system services raises or winzes to 300 ft, operating at 50 fpm (feet per minute), with a man-rated payload of 500 lb, or a maximum payload of 1,250 lb with cage removed. The personnel cage is readily detachable to facilitate hoisting bulky or awkward materials or equipment such as timber, pipe, slushers, or machinery components. The frame and guide structure are necessarily site-specific; however, the drive unit, with appropriate chassis and guide structure, is adaptable to operation through any opening that dips in excess of 45° with a minimum 25- by 29-in rectangular, or 30-in-diameter circular cross section.

The system adheres to all applicable State and Federal regulations. It is self operated, eliminating the need for a hoistman. Fail-safe features are incorporated in the control and power systems. The hoist requires a 489-V, three-phase power supply, normally available underground. The controls operate on 15 Vdc, converted from the main power supply. The main brake is power-release, thus is set in the event of a power failure. Independent, dual,

A compact hoist system has been developed for the vertical transport of personnel and supplies to and from the stopes in underground vein mines.

mechanically operated, secondary brakes operated from overspeed governors provide secondary emergency braking. An overload or slack-rope condition on either rope will stop the system. Automatic normal and overtravel sensors stop the hoist at the top and bottom of travel. Telephone, light, and horn communication exist between the cage and all control stations. The hoist must be released to transfer control, but any stop button will stop the system.

A prototype system has been fabricated, tested on the surface, and is being readied for installation in an operating mine for testing under production conditions.

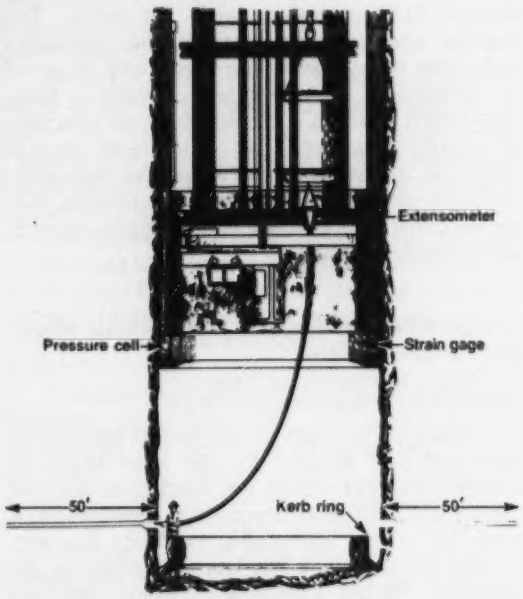
Design Criteria for Shaft Support

M. J. Beus, Principal Investigator
Spokane Research Center, Spokane, Wash.

With development of deeper ore deposits, higher rock pressures result in increased ground control problems. These problems are particularly severe in a mine shaft which must be maintained throughout the life of the ore body. Up to $500,000 per year can be spent on each shaft just for repair and maintenance in a typical deep mining area.

Field and laboratory studies are being conducted to develop design criteria and define the structural parameters that are important in designing and maintaining a stable mine shaft. Several investigative approaches are underway, including in situ stress and physical property measurement, finite-element modeling, and instrumentation of full-size shafts now under construction.

In situ stresses have been measured and statistically analyzed at several locations from 1,200 to 7,300 ft underground, near existing or potential shaft sites. Material properties are determined both in situ and by laboratory testing. Two- and three-dimensional finite-element analyses are conducted using the field-determined stress values as input.



Instruments installed in an 18-ft-diameter circular shaft measure rock movement and concrete pressure. The data obtained are used to develop design criteria and define structural parameters important in designing and maintaining a stable mine shaft.

In situ ground stress, physical properties, and geologic features, such as joints, bedding planes, and faults, are considered as "fixed" conditions. Shaft shape, size, orientation, face distance, time to support, and support system can be chosen by the designer to maximize the structural performance of the shaft. Many combinations of "fixed" and "variable" conditions are possible and analyses have shown that some are more important than others. For example, orientation for noncircular shapes has a dominating effect on stability, while the type and dimension of the support system is not as critical as previously thought.

Full-size shafts currently under construction are being instrumented to measure rock movement and support pressure. Results from these measurements show that geologic structure affects displacement of shaft walls more than in situ stress, in some cases, and efforts are being focused on more accurate classification of rock mass discontinuities. Data also indicate that shaft support develops less internal pressure than expected. Further in situ testing will verify these trends and serve as a guide to development of more realistic design criteria.

Improved Skip Designs for Increased Production

Eugene H. Skinner, Technical Project Officer
Spokane Research Center, Spokane, Wash.

As mining depths increase and ore grades decrease, shaft hoisting capabilities of many deep mines have become inadequate. To alleviate this problem, the Bureau has developed new skip designs and a guide-alinement measuring system (GAMS) that can increase hoisting payloads and speeds, and improve the life and ride characteristics of shaft conveyances.

Two experimental skips—one aluminum and one fiberglass—have been fabricated with innovative design features: Both have cylindrical skip bodies with frame and bail assemblies that emphasize selective preloading of the guide rollers. The cylindrical skip bodies utilize the superior stress distribution of shell structures rather than heavily reinforced stiffener designs common in the square skip body.

In the case of the aluminum skip, a weight savings of nearly 2 tons was achieved over a steel skip for the same 110-ft^3 (cubic foot) capacity. The fiberglass skip body will weigh about the same as the aluminum one because a thicker section is needed for the same strength. The fiberglass has the advantage of low cost and can be discarded at

A Bureau-designed cylindrical aluminum skip has been installed in an operating mine. The cylindrical body has the same cubic-foot capacity as the rectangular body it replaced, yet weighs about 2 tons less. The block below the skip is used as a weight to maintain hoisting counterbalance.

the end of the design life. To lengthen skip life, a double-layer elastomer lining with color coding is used, enabling points of high wear to be determined by visual inspection. The aluminum skip has been installed in an operating mine, and the fiberglass skip will soon be installed to run in counterbalance with it. Corrosion-resistant coatings and paints were also applied to the skips.

The GAMS instrumentation for measuring guide alinement incorporates a recorder for the depth, the face-to-face guide distance, the angle of guide twist, and the guide inclination and azimuth angles. These data are recorded with an onboard magnetic-tape unit during conveyance travel. Replay of the tape on the surface can provide a direct plot of all measurements versus shaft depth. The data can be fed to a computer program (SKIP II) to compute the forces acting on the guides caused by their misalinement. This will allow mine management to make corrections in shaft alinement. Prior to GAMS, guide alinement was measured with a plumb bob and tape measure. The SKIP II computer program is the first work ever done to use the equations of skip motion to compute skip and guide interaction forces. Few mines actually hoist at the maximum allowable speed of 2,500 fpm (feet per minute) because of shaft misalinement. Most mines compensate for shaft misalinement by decreasing shaft hoisting speed.

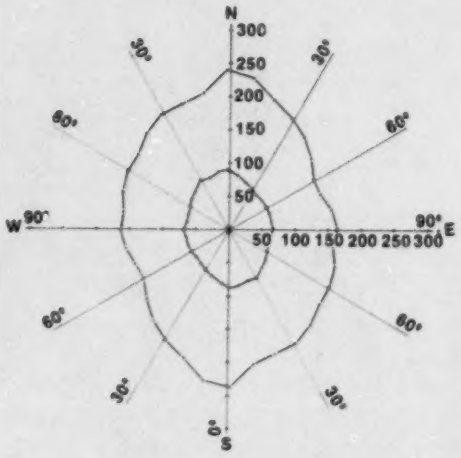
Lightweight skips combined with faster hoisting speeds offer the benefit of increased production with less energy consumption. For the same tonnage hoisted with lightweight skips, the rope size may also be sized smaller. This reduces hoisting power costs as well as the capital costs of the hoist installation.

Resource Conservation Technology

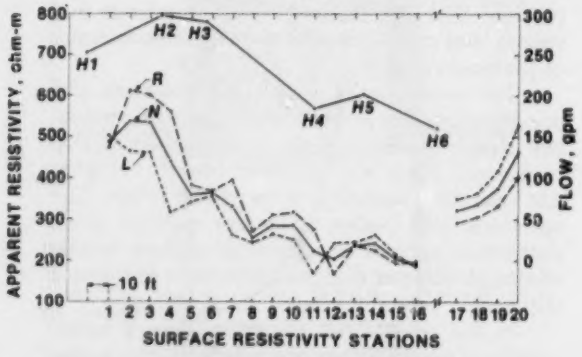
Development of Geophysical Methods for Measurement of Joint Characteristics

Patricia J. Leonard-Mayer, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

The ability of hydrologists and engineers to predict the flow of ground water through jointed formations and into mines and quarries is limited by the field methods available for measuring the hydrologically significant characteristics of the jointed rock. The methods available for measuring joint orientation, width, spacing, and dip include direct measurement of joints exposed at outcrops and roadcuts, examination of recovered cores, and borehole logging. The disadvantage of these methods is that outcrops may not represent the jointed rock located some distance away because of lateral changes in the formation geology or intense weathering of the outcrop, and because measurements on cores and in boreholes represent a small volume of rock. The Bureau is developing



Data from resistivity station 1 (outer) and 12a (inner) are plotted as a function of azimuth and indicate the strike of the fracture.



A resistivity zone (surface stations 8-16) has a corresponding loss of flow (stream stations H4-H6). The low-resistivity zone was ultimately interpreted as a zone of greater joint frequency.

Taylor (left) and horizontal (right) profiles were used to determine orientation of joint sets and detect changes in joint frequency in coal overburden at the Shannopin Mine in Green County, Pa.

indirect (surface) methods for measuring the characteristics of jointed rock in order to predict ground water flow through the formation. A surface resistivity method, called the Taylor method, has been developed in the first phase of the Bureau's effort.

The Taylor resistivity method has been used to determine orientations of joint sets. The method consists of an azimuthal or oriented resistivity survey used in conjunction with standard resistivity methods. The resulting apparent resistivity data can be interpreted graphically by plotting resistivity as a function of direction on polar coordinate paper. If the plot is elliptical, its long axis indicates the strike of a joint set. Multiple joint sets result in additional high points on the apparent resistivity plot. The method has been used successfully to determine joint orientations in limestone, dolomite, and sandstones, in single and multi-layered aquifers, and to depths of approximately 100 ft.

Surface resistivity was measured and a horizontal profile was made to delineate joint orientations and detect changes in joint frequency in coal overburden. The site of the study was above a relatively wet section of the Shannopin Mine in Greene County, Pa. A zone of low resistivity was located using the resistivity methods and was ultimately interpreted as a zone of greater joint frequency. Later detailed flow measurements in a small stream crossing the zone showed a significant loss of flow corresponding to the low-resistivity zone. The zone of higher joint frequency will eventually be grouted, and mine water will be closely monitored to document the predicted reduction of inflow. The fracture orientations determined by the Taylor method were in approximately N-S, E-W, and NW-SE directions. The E-W and NW-SE directions correlated with joint orientations measured in the stream bed at the site; the E-W orientation corresponds to a regional joint set. Further study will indicate if the N-S fractures are related to subsidence.

The resistivity methods have proven to be extremely useful while they are inexpensive and simple to use in the field. The structural information obtained by use of the method is expected to be useful in many mining applications, including nonhydrologic applications such as the design of blasting patterns for pits and quarries. Additional uses and limitations of the method are still under study, particularly for determining joint width and spacing. Other geophysical methods are also being evaluated for applications in predicting ground water movement through formations.

Predicting Mine Water Inflow

Bill M. Stewart, Technical Project Officer
Spokane Research Center, Spokane, Wash.

Underground mines frequently encounter problems with ground water inflow both during the sinking of the shaft and during drift development. This inflow can be minor or can occur in large quantities that jeopardize the entire project. Problems are frequently incurred during the initial shaft development when large inflows of ground water can severely hamper shaft sinking. Actions taken at this point are extremely critical owing to the short amount of time available to prevent flooding of the shaft. If the inflow has been predicted and is expected, the problem can be handled expeditiously. Ground water inflow to the drifts can be a long-term expense owing to the obvious costs of pumping, health and safety costs, and increased equipment wear.

The Bureau initiated a study designed to enhance the prediction of mine water inflow rates. The objective of this study is to evaluate the hydrologic variables associated with surface and ground water systems that affect inflow of ground water into an underground mine. Data collection techniques were reviewed for their applicability for quantifying these hydrologic variables. Existing analytical and numerical procedures for predicting underground mine water inflow were reviewed and evaluated.

Over 300 computer models were reviewed for their applicability to modeling underground mine water inflow. A finite-element model, UNSAT2, was used to model inflow to a shaft and a tunnel or drift. The technique developed for predicting underground mine water inflow evaluates the sinking of the shaft through different hydrostratigraphic units, considering both the variations in hydraulic conductivity among the units and the diameter of the shaft and the shaft sinking rate. This technique facilitates the prediction of inflow into a shaft using the concept of partial penetration, whereas most techniques used in the past have considered the shaft as a line sink. The technique developed under the study can also evaluate the inflow into a drift or tunnel. Ground water inflow into a drift is simulated in a two-dimensional plane, perpendicular to the drift. Using the horizontal mode of operation of UNSAT2, complex boundary conditions can be evaluated.

The technique developed was applied satisfactorily to two active mines. At the first site, the simulated flow into the shaft and drifts agreed well with actual discharge reported by the mining

company, assuming the drifts extend in a straight line away from the shaft. At the second site, average simulated inflow was 640 gpm (gallons per minute) versus a reported inflow of 600 to 800 gpm.

The results of this study will be available in a future publication that will include a detailed description of the predictive techniques and their application to existing mines.

Blast Design To Minimize Airblast and Ground Vibration

John W. Kopp, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

The Bureau has recently released structural response criteria for various airblast and ground vibration levels. These criteria can now be used in blast design to minimize impact to residential structures located close to mining operations. In addition, explosives manufacturers have introduced many innovations in blasting technology with emphasis on better fragmentation. The effects on blast design of initiation and timing methods, explosive charge per delay interval, and use of decking are now being studied. Several initiation timing schemes have been tried as well as use of decked versus undecked holes.

Field tests were performed at a large coal strip mine in southern Indiana. Airblast and ground vibration levels were measured using arrays of self-triggered seismographs. The arrays were arranged as lines radiating from the shot in the four compass directions. Distances from the shot to the instrument varied from 200 ft to over 1 mile. Each shot was recorded on film using a high-speed camera to observe the firing sequence of the millisecond delay caps. The film also shows any holes firing out of sequence or blowouts.

Analysis of the data so far indicates that peak levels of airblast and ground vibrations are dependent on direction of blast initiation, and intervals between delays affect the levels. Spectrum analysis of the airblast and ground vibration time

Typical monitoring of a blast at a mine site.

histories have also been performed. Results indicate that predominant frequencies are more dependent on geology than on blast design at distances over 1,000 ft.

Fieldwork is continuing with the goal of optimizing the blast design with respect to airblast and ground vibration levels.

Fatigue Effects of Repeated Blasting

Mark Stagg, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

Damage caused by ground vibrations from surface mine blasting is a serious problem for the mining industry. The Bureau has recently completed two major studies to determine the airblast and ground vibration levels that correspond to structure response and the thresholds of minor and major cracking of interior walls. Criteria were recommended for safe levels of both airblast and ground vibrations which, if followed, will greatly reduce the probability of blast damage.

These studies of 76 residences were, by design, short-term tests at relatively high vibration levels, and most of the damage observed consisted of extension or generation of cracks in older plaster walls. There existed no long-term control of the loading conditions and very little could be learned about fatigue due to repeated transient loading. Consequently, a residential structure was built jointly with AMAX Coal Co. at the Ayrshire Mine, Evansville, Ind., and it was subjected to a 2-year program of fatigue testing. During this period, vibration and strain measurements were made throughout the structure to assess the relative effects of repeated blasting, aging, settlement, weather, and normal household activities.

Complementing this field study, laboratory tests are being conducted to determine the failure characteristics of house construction materials and substructures and a program to conduct dynamic tests of block walls is being developed with the National Bureau of Standards. Drywall failure tests demonstrate that the core cracks with no visual indication in the paper and this is followed by paper cracking at higher strains. Even in critical areas (areas of high stress such as over doorways) in the test structure, strains did not approach core failure strain levels until vibrations of over 5 in/sec (inches per second) were attained.

A residential test structure, built in the path of a coal strip mine, was instrumented to obtain data on effects of repeated blasting, aging, settlement, and weather over a 2-year period.

The results of the test structure fatigue study will be combined with the laboratory fatigue tests and previous short-term peak level measurements to establish criteria for prevention of fatigue damage to residential structures and their construction materials. The relationship of fatigue damage due to blasting compared with the damage due to natural influences will also be defined.

Blasting Effects on Water Wells in Appalachia

John W. Kopp, Technical Project Officer
Twin Cities Research Center, Minneapolis, Minn.

Appalachian surface coal mine blasting has been claimed to be responsible for water well damage in 36 cases reported in the period from 1970 to 1975. From turbidity to total water loss, these claims suggested an extent of blast damage heretofore unsuspected and unobserved.

The Bureau investigated the effects of blasting on ground water supplies in a two-phase program. The first phase involved investigation of the 36 damage claims, and the second phase was a field study at five mining sites, four of which were in Appalachia.

Most private wells in Appalachia are fracture systems with yields of less than 1 gpm (gallon per minute). They are generally not of high quality and have a variety of design problems. In essentially all damage cases, initial specific capacities are unknown. Of the 36 reported claims of blast-damaged wells, 24 were investigated in the field. No clear evidence was found that the well problems were blast related. In most cases, it was evident that other factors were responsible for the changes in well behavior.

Four Appalachian sites were chosen for the field study on the basis of geographic and geologic diversity. At all sites, pumping and observation wells were drilled for drawdown tests. In addition, water quality, static water level, and blast-produced vibrations were monitored as blasting approached within 50 ft of the test areas. Despite high vibration

levels (peak particle velocities over 5 in/sec (inches per second)), no blast damage was found other than the possible dislodgement of red slime from iron bacteria.

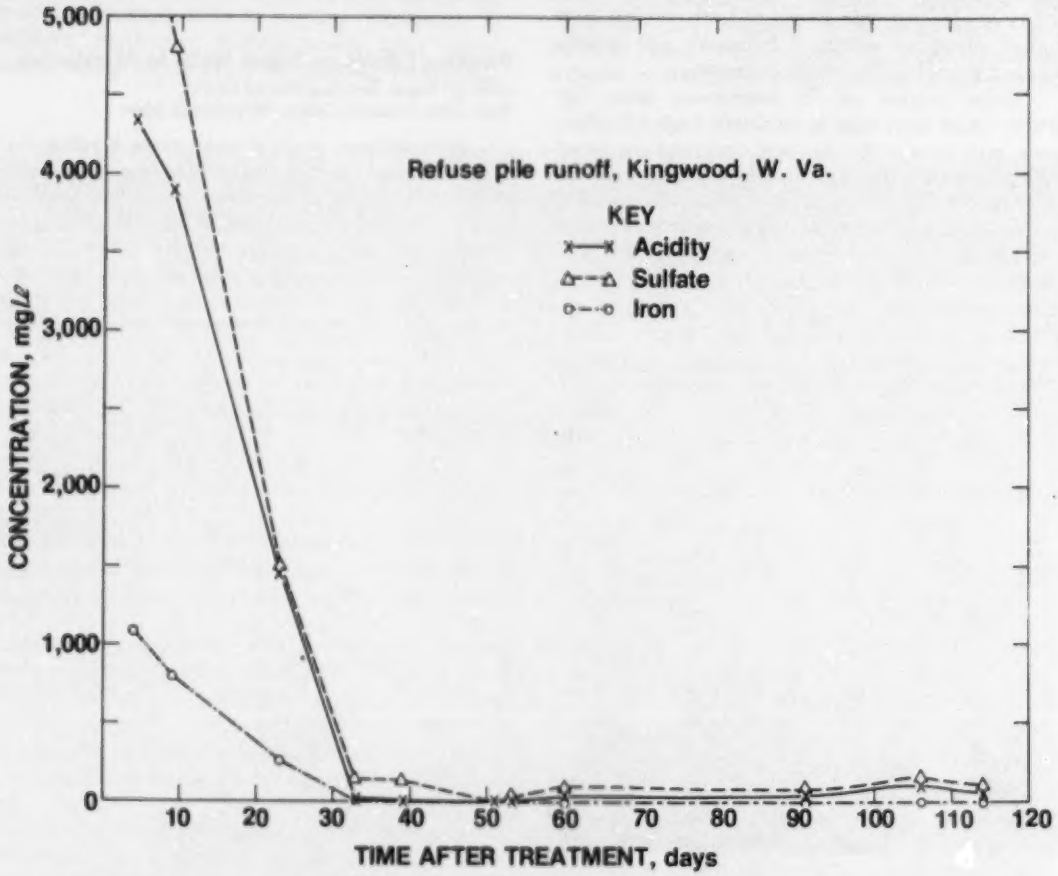
However, at three sites the mining excavation appeared to influence wells within approximately 300 ft. An abrupt drop of static water level was observed, followed by an increased specific capacity. This drop was attributed to an opening of the fractures from lateral stress relief. In other words, an increased storage space and hydrogeologic permeability resulted. It is expected that additional rainfall would bring the static water level up to its previous elevation. It is noteworthy that shallow wells could temporarily lose water under these conditions.

It was concluded that the largest vibrations likely to be produced by surface mine blasting (a peak particle velocity of 2 in/sec) are not damaging to water wells.

Acid Mine Drainage Prevention—Use of Surfactants

R. L. Kleinmann, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

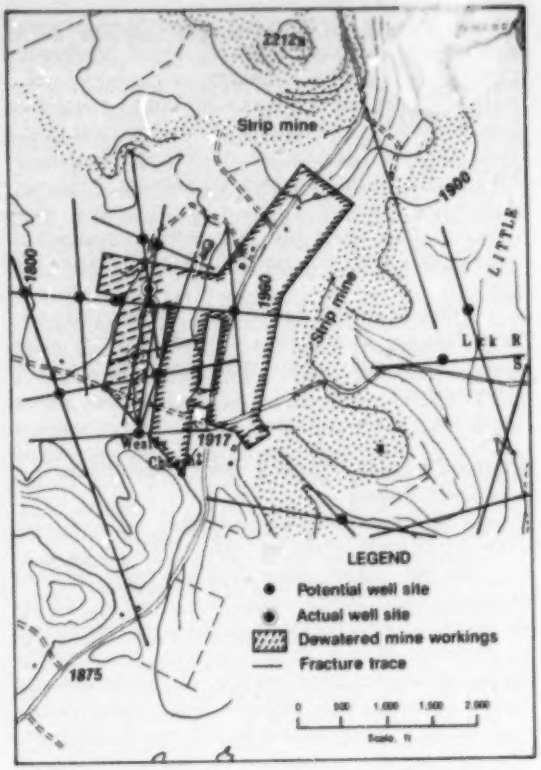
Acid mine drainage from abandoned mines pollutes more than 5,000 miles of streams in the United States. The iron-oxidizing bacterium, *Thiobacillus ferrooxidans*, plays a critical role in determining the rate of pyrite oxidation and, consequently, the rate of acid mine drainage formation. The Bureau has investigated the use of anionic surfactants as a method to inhibit this



Concentrations of acidity, sulfate, and iron decreased sharply after treatment with sodium lauryl sulfate at active section of a large refuse pile near Kingwood, W. Va.

organism. Common surfactants, such as sodium lauryl sulfate (SLS), have been shown to control *T. ferrooxidans* and thereby reduce acid production 60 to 90 pct.

At a 10-acre inactive refuse pile near Beckley, W. Va., SLS was applied by hydroseeder at a rate of 55 gal of 30-pct detergent solution per acre, with a dilution factor of about 1:1,000. After a 3-month interval, average acidity decreased from 900 mg/1 (milligrams per liter) to 350 mg/1, and iron decreased from over 100 mg/1 to 2 mg/1. Before application, water treatment had cost the operator $7,500 per month; after the water quality improved, the operator was able to simply mix the effluent with an available source of slightly alkaline mine water and discharge it. An 8-acre active section of a large refuse pile was treated in a similar manner near Kingwood, W. Va. Acidity and sulfate decreased from over 4,000 mg/1 to less than 100 mg/1 and iron decreased from 1,000 mg/1 to 2 mg/1 or less. The cost of SLS was approximately $200 per 55-gal drum at both sites; the effect at these sites has so far lasted 4 months. SLS has been detected in the discharge at concentrations of only 0.2 mg/1 or less. At two other sites, SLS was applied both in solution and in slow-release rubber pellets. The latter method of SLS application is expected to provide long-term control of acid drainage from inactive sites where periodic reapplication would not be feasible.



Large volumes of ground water stored in natural fracture zones in the vicinity of a mine can be removed before coming in contact with mine workings thereby decreasing water inflow problems and attendant acid mine drainage treatment costs.

A Fracture Dewatering Strategy for Underground Coal Mines

Robert D. Schmidt, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

The Bureau has developed a strategy for dewatering underground coal mines that is an environmentally and economically attractive alternative to pumping and treating large volumes of acid mine drainage (AMD). This dewatering strategy exploits the natural geologic occurrence of fractured rock zones as the most productive sites for dewatering well development. With careful consideration given to cost effectiveness, dewatering operations are concentrated on removing a large volume of ground water stored in fracture zones in the vicinity of the mine, rather than attempting to create an expansive cone of depression in the unfractured rock matrix.

Fracture traces (the surface expression of fractured rock zones) in the immediate vicinity of the mine workings are located through low-level aerial photographic and geologic investigation. Dewatering wells are then sited precisely on fracture trace intersections in order to take advantage of the increased pumping capacity made possible by locally high permeability. Ground water pumped from fracture sited dewatering wells is generally of high quality since it has not yet contacted mine workings. If mine or local domestic use is impractical, it can very often be discharged on the surface without prior treatment.

This dewatering strategy was tested at a small underground mine in West Virginia, operating in the Upper Freeport Coal seam. The mine had a history of severe water inflow problems and attendant high AMD treatment costs. Three 200-ft-deep wells were drilled and pumped to dewater five developing entries in the mine over a period of 4 months. Dewatering wells developed on fracture intersections in advance of mine workings sustained 24-hr pumping capacities of 300 to 500 gpm (gallons per minute), 10 to 20 times greater than

nearby wells in nonfractured zones. Storage water was initially depleted after 24 hr of continuous pumping. Thereafter a maintenance schedule of 3 hr of pumping per day was sufficient to maintain a low level of fracture storage. With approval of the West Virginia Department of Natural Resources, high quality ground water from these wells was discharged, untreated, into a nearby creek. Mine water outflow from the five entries dropped to nearly zero from the original high of about 100 gpm.

Fracture-zone dewatering developed and demonstrated during this research appears especially well suited to new mine and isolated entry development.

Removing Heavy Metal From Copper-Nickel Stockpile Runoff

Peter G. Chamberlain, Principal Investigator
Twin Cities Research Center, Minneapolis, Minn.

Natural runoff water draining from lean-ore stockpiles and waste rock piles that would be generated during copper-nickel mining operations in northern Minnesota will contain unacceptable levels of several toxic metals. Measurements on runoff from test piles indicate that copper, nickel, and cobalt concentrations in the runoff water will exceed proposed EPA standards. Failure to develop techniques to reduce the concentration of these heavy metals will prevent mining of the sulfide ores in the district. Conversely, successful abatement techniques developed for this region would apply to many other districts where sulfide ores are mined.

The Bureau is evaluating methods of reducing toxic trace metals in runoff water. Since the metallic mining industry is economically depressed, any abatement method must be low in cost and personnel requirements (passive). The research approach was to investigate the capabilities of several materials that might function in a passive system to adsorb trace metals from runoff water. Peat, glacial till, copper-nickel tailings, taconite tailings, zeolite, and woodchips were all considered. Laboratory tests showed that copper-nickel tailings and a peat-tailings mixture were the best in terms of adsorbing capacity, permeability, cost, and availability. The tests indicated that approximately 40 bed-volumes of runoff water could pass through a tailing bed before the adsorbing capacity was effectively exhausted.

To verify these results, a field test is underway in northern Minnesota. Drainage from lean-ore test piles is being channeled through two different types of treatment beds containing tailings. These beds

Test treatment beds constructed at the toe of a copper-nickel mine lean ore stockpile are used to determine their ability to remove trace metals from stockpile drainage.

were constructed so that influent and effluent water can be monitored for quantity and quality. A treatment strategy involving mixing the tailings and waste rock as it is being placed will be tested at the same site.

The test results will enable evaluation of the size and the costs of treatment beds required for any particular runoff quality and quantity. The methods developed should apply to abandoned mine sites as well as operating mines in any district where sulfide ores are mined.

Use of Cemented Backfill To Prevent Subsidence Damage and Increase Production

Thomas R. Bur, Technical Project Officer
Twin Cities Research Center, Minneapolis, Minn.

A Bureau study to evaluate the feasibility of disposing of some or all of coal related waste as cemented backfill in active coal mines to prevent subsidence damage has been completed. A mixture of at least 55 pct of coal waste and high early strength type III portland cement can be made to form a cemented backfill that will reach a uniaxial test strength of 500 psi (pounds per square inch) in one day. Preliminary tests indicate that 100 pct of the coarse wash plant waste and bottom ash, 40 pct of the fly ash, and 13 pct of the flue gas desulfurization sludge would be utilized in an optimum mix consisting of about four-fifths waste and one-fifth portland cement. The use of all of the coal waste in a cemented backfill is not feasible. Even a mix of two-thirds waste and one-third portland cement failed to give strength higher than about 50 psi. This low strength was thought to be associated with clay and fine particles in the fine wash plant waste. However, waste that is unsuitable for cement could be placed as loose backfill utilizing the same stowing system. Use of cemented backfill for longwall and shortwall mining was not considered feasible, largely because of curing time.

Cost estimates were developed based on a hypothetical system for room and pillar mining with partial extraction. An estimate for pneumatic stowing with a dry-mix method in a partial extraction mine was $14.39 per ton of waste. By combining the use of cemented and uncemented backfill, the cost was reduced to $9.19 per ton of waste. Normal surface disposal cost for the model mines would have been $6.47 per ton of waste. Thus the use of cemented backfill in active mines is economically feasible when the value of subsidence prevention is equivalent to approximately $2.75 per ton of waste.

In addition, the use of cemented backfill could substantially increase the percentage of coal extraction while maintaining an allowable measure of roof support to prevent subsidence. Such application would have many benefits that were beyond the scope of this study. The mixture used in the study required roughly 80 lb of coal waste per cubic foot of cemented backfill. If a mining seam density of 80 lb/ft^3 is assumed, a simple one-to-one relationship between the fraction of the mined out area that can be supported by backfill and the percentage of the mined seam that is utilized in the cemented backfill can be used for making estimates. To illustrate, a mine having 25 pct of its mine product as usable waste for cemented backfill could increase its total extraction by a factor of 1.33. If the allowable percentage of roof that could be unsupported over a long term were 45 pct, the mine could extract 60 pct and backfill to an effective 45 pct for subsidence purposes. In the process, 15 pct of additional resources would be recovered.

For a given mining rate the active mine life and gross income from a given block of coal resources would increase substantially. Since the increase in production would be handled by the existing facilities, average production cost per ton would decrease. A decrease of $2.00 to $3.00 per ton in mining cost should make backfilling economically feasible. The benefit of higher recovery to the long-range needs of the country and of the extended mine life to the community are self evident.

Development of Slurry Backfill for Oil and Shale Mining

David E. Nicholson, Technical Project Officer
Spokane Research Center, Spokane, Wash.

The modified in situ retorting process has been investigated by the oil companies for the past decade. In the process, the oil shale formation is partially extracted for surface retorting, and the remaining shale formation rubblized and retorted in place in large underground caverns. Thus, significant amounts of spent shale ash generated from the surface retorts need a disposal method, and the large rubble-filled voids underground require filling to seal and stabilize the mine during its productive life.

The Bureau has successfully developed a filling and grouting technique for sealing in situ retorts with the cementitious spent shale ash generated in the surface retorts. Originally, slurries made from the ash and water were not satisfactory

Spent shale ash generated from surface retorts is mixed and blended with additives for injection as grout and backfill.

because of rapid setting of the grout (5 min) and high slurry viscosity which made long-range pumping and placement impractical. Initial research investigated numerous additives. The addition of small amounts of gluconic acid to the slurry increased set time to 1.5 hr, the Marsh viscosity reduced to about 50 sec, while the grout retained sufficient strength to make a satisfactory backfill.

Three large-scale tests were performed to further test the grout. Two rubble-filled, 5-ft-diameter by 12-ft-high tanks were injected with the spent shale ash grout. A majority of the grout was placed at 50 psi (pounds per square inch) pressures. Thus, the grouting process could utilize the common elevation head in an oil shale mine for injection and not experience excessive pumping costs. A buried trench test was performed to determine the ease of lateral penetration of the grout through the spent rubble. In this test, the grouting pressures were reduced to 10 psi with complete penetration of the grout through the length of trench.

Results of the program indicate that excellent grouts and mine backfills can be obtained from spent shale ash. The cementitious backfills will be essentially impermeable to ground water flow and have good strength properties which will assist in stabilizing oil shale mines and allow the utilization of alternative mining methods and the recovery of mine pillars.

Controlled Burnout of Underground Coal or Waste Bank Fires

R. F. Chaiken, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

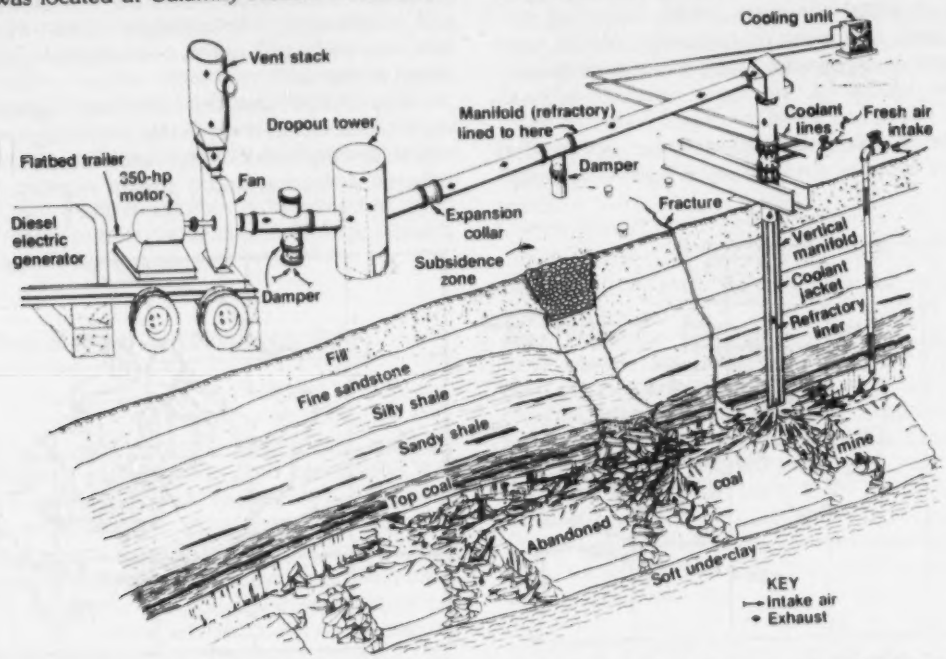
More than 500 fires are now burning in abandoned coal waste banks and coal deposits in the United States. Once established, such fires can burn for decades. Extinguishing them by conven-

tional methods such as surface sealing to exclude air, excavation to remove fuel, or flushing to cool the fire zone, is usually difficult and always expensive.

Controlled burnout, a new technique being developed by the Bureau for the treatment of abandoned coal fires, involves the accelerated combustion of coal in place with total management of heat and fumes produced. In controlled burnout, a burning waste bank or abandoned underground mine is placed under negative pressure relative to the atmosphere. Heat and combustion products are drawn from the combustion zone through an exhaust ventilation system. Heat produced by controlled burnout appears as sensible heat in the exhaust, at temperatures as high as 1,000° C. It can be recovered for the production of steam, hot water, process heat, and electricity. Air is drawn into the combustion zone through natural fractures and crevices, or through air-inlet boreholes. The fire propagates in the direction of the air supply and is self-extinguished when the fuel is consumed. The extent of the fire is controlled by natural barriers, such as outcrops or faults, or artificial boundaries such as flushed barriers or trenches.

The Bureau's first controlled burnout experiment was located at Calamity Hollow in Jefferson Borough, Pa. In the early 1900's, Calamity Hollow was the site of an underground mine, and it was surface mined in the 1940's. In the winter of 1961-62, a fire of undetermined origin was discovered in the exposed coal. In 1963, a trench barrier was constructed around the fire and a surface seal placed over the affected area, but at the start of the controlled burnout demonstration the fire was still smoldering in 1.5 acres.

The controlled burnout installation consists of a diesel generator, an electric motor and exhaust fan, a dropout tower, a horizontal duct, and a vertical manifold pipe that extends 25 ft below the surface to the top of the mine void. The pipe is water jacketed and lined with refractory brick; it serves as exhaust point for the heat and gases produced during combustion. Boreholes located around the exhaust system let air into the combustion zone. A 40-ft section of the horizontal duct is refractory lined and acts as an afterburner to insure complete combustion of the exhaust gases. Valves in the duct control suction in the mine and introduce cooling air into the duct. As currently implemented the burnout ventilation system exhausts the heat to the atmosphere. The dropout tower collects any large particles sucked out of the mine and can be fitted with a scrubber system, if



Controlled burnout is used to treat abandoned coal mine fires. Fresh air is drawn into the fire zone and combustion products are removed through a vertical manifold and vent stack.

required. Flow rate, gas composition, temperature, and static pressure are monitored on instruments in a trailer located 150 ft from the fan.

Continuous burn operations (24 hr a day, 7 days a week) were completed May 1, 1982. The temperature in the exhaust manifold varied from 500° to 950° C; the thermal output was 3 to 6 MW (megawatts), and the estimated coal consumption rate was approximately 10 tons per day. The combustion zone will be excavated, while operating the exhaust system to control fumes from the cooling fire, so that the progress of the underground fire can be traced, the effect of high temperatures on surrounding strata can be determined, and the nature of the coal residue can be analyzed. When studies are completed, the site will be backfilled and regraded.

Computer Modeling of Surface Coal Mining Effects on Ground Water in the Powder River Basin

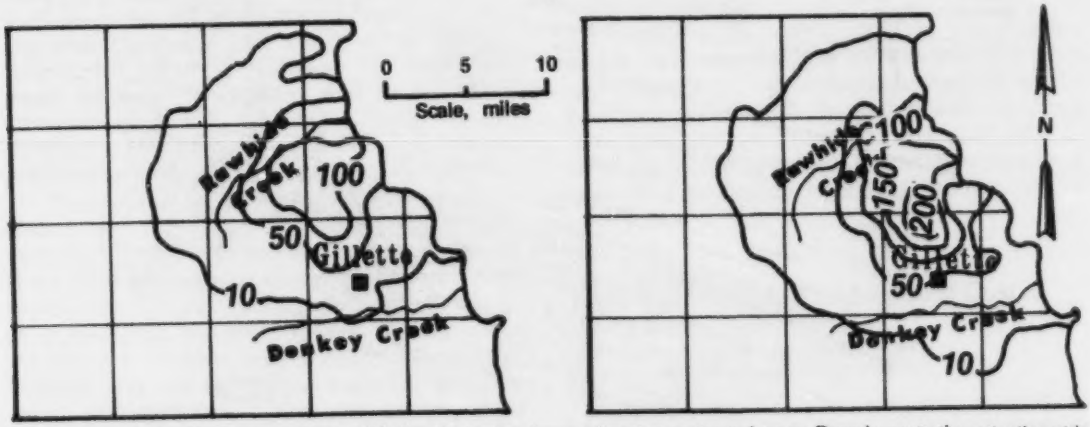
Gary E. McIntosh, Technical Project Officer
Denver Research Center, Denver, Colo.

Passage of the Surface Mining Reclamation Act created a need for a method to determine the cumulative hydrologic impact of surface coal mining. A digital computer model, based on the Prickett and Lonnquist ground water model, was developed as a potential solution to this problem.

The model of the area centered around Gillette, Wyo., had a grid spacing of 2 km and used a two-layer assumption. Overburden above the persistent Wyodak-Anderson coal seam was designated as the upper aquifer (layer) and the coal seam itself was designated as the lower aquifer. A leaky confining bed was assumed to exist between the two layers to account for leakage between the two separate aquifers. Actual subsurface structural conditions occurring within the subregional area were incorporated into the model by assigning elevations for the ground surface and the tops and bottoms of each layer based upon U.S. Geological Survey topographic, structural, and isopachous maps. Constant heads were assigned to the north, south, and west boundaries based upon actual observed values. The eastern boundary was delineated as a no-flow boundary along the Wyodak-Anderson coal seam outcrop. The grid size was made large enough that head changes during the impact analysis would not encounter the northern, western, or southern boundaries.

The model accounted for induced infiltration along intermittent and perennial streams and for leakage between layers. To deal with uncertainties in the available transmissivity data, a stochastic (a Monte Carlo technique) approach was taken. This approach involved repeated simulations using different transmissivity fields selected randomly from normal distributions that were defined from the means and standard deviations of known coal and overburden transmissivity data. Modeled heads at each grid node were expressed over a statistical interval.

The model was first calibrated against the known head distribution in the area using uniform hydraulic conductivities for each layer. Natural recharge, leakance, and a stream recharge factor



Computer modeling has been used to predict the effects of surface coal mining on ground water. Drawdowns in the potentiometric surface of the coal aquifer (left) extended 8 to 10 miles from a hypothetical mine and drawdowns in the overburden aquifer (right) potentiometric surface extended from 6 to 8 miles.

were varied to arrive at acceptable head distributions for each layer, and ground water baseflow for each modeled stream.

Three mines, containing three pits each, were placed in the vicinity of Gillette, Wyo., to simulate cumulative hydrologic impact. Assumptions used to characterize these mines were considered conservative or "worst case" for the evaluation of impacts in an east-west direction. Pits were represented by assigning a constant discharge at each mine node throughout the period of the simulation.

Twenty simulations were run to provide a suitable sample size. Each run involved generating a steady-state head surface using randomly selected transmissivity fields, and then placing the mines in the model and observing transient impacts over a hypothetical 30-year mining period.

Since mining is expected to take place in a north-south direction along the coal outcrop, impacts in this direction are limited only by the length of the mined area. Impacts for any given east-west cross section are, however, a function of a predictable finite density of mines along the cross section. Predicted impacts were therefore viewed in an east-west direction.

Drawdowns in the potentiometric surface of the coal aquifer were predicted to extend from 8 to 10 miles from a given mine. Drawdowns in the overburden aquifer potentiometric surface extended from 6 to 8 miles. This order of magnitude has been predicted by other researchers, although less drawdown has actually been observed in the field to date.

Future research efforts will be aimed at using the model to predict cumulative hydrologic impacts of different mining scenarios.

Inventory of Metal and Nonmetal Waste Disposal Sites

Barbee J. Scheibner, Technical Project Officer
Spokane Research Center, Spokane, Wash.

Solid waste disposal regulations and the growing lack of high-grade ores necessitates that industry and Government reevaluate present mine waste embankments or tailings to determine potential environmental damage, suitable disposal sites, potential recycling value, and secondary uses.

To aid this reevaluation, the Bureau completed an inventory of metal and nonmetal waste disposal sites in the United States. The necessary mine, mill, and smelter baseline data were collected to enable the mining industry and associated Government agencies to initiate the development of advanced techniques or methods in the handling, disposal, and potential reuse of future mine or mill tailings.

Over 500 individual operations that met the 50,000-tpy (tons per year) production criterion of the study were identified. A data sheet was completed for each mine, mill, and smelter operation. Data included (where possible) acreage and/or volume, mining methods, primary ore and gangue minerals, waste composition and haulage, and methods and distance hauled.

Each mine, mill, and smelter was located on a map of the United States along with annual and accumulated waste tonnage, climatic, vegetative, geologic, and elevation-topographic overlay information. This map, with overlays, has been digitized and can be easily reproduced, revised, and updated.

Aerial photographs of mine locations throughout the United States were subjected to imagery-interpretation techniques and methods to ascertain mine and waste acreages and the approximate tonnage of waste at each site. Sectional maps, based on U.S. Geological Survey quad sheets and the aerial photographs, were prepared delineating mine, mill, and smelter acerages, and waste pile volumes and tonnages.

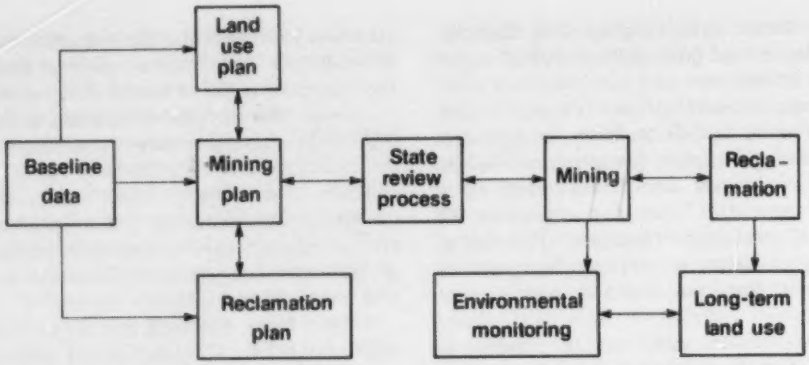
The data have been encoded and an informative storage and retrieval system established for ease of reference and periodic updating.

Development of Metal-Nonmetal Waste Disposal Design Guide

Lani Boldt, Technical Project Officer
Spokane Research Center, Spokane, Wash.

A waste disposal design guide has been developed to assist Government agencies, engineers, and planners through the mine waste disposal process. Disposal of metal and nonmetal mine waste must be considered in the very first mine planning procedures. In this way, many of the physical, regulatory, and aesthetic constraints can be met and dealt with before mining begins and before economic and technical remedies become necessary. Included in the manual are sections or waste disposal planning, legislation and regulations, future land use planning, geotechnical investigations, waste disposal methods, design procedures, construction, operation and maintenance, instrumentation, and site rehabilitation. Appropriate references following each chapter provide more detailed data on material presented in the text.

While a single text cannot comprehensively



By considering disposal of waste in the mine planning stage, constraints can be met and dealt with before mining begins and economic and technical remedies become necessary.

cover all aspects of mine waste disposal, this manual guides the reader through the intricacies of waste management by systematically approaching the problem and offering important details along the way. For example, while there are no specific Federal regulations for the disposal of metal-nonmetal wastes at present, many permitting and leasing actions and generic regulations exist that could possibly impact a particular mine site. These are listed in the manual along with Federal and State agencies, their locations, and telephone numbers.

Disposal of Mill Tailings in a Surface Backfill

Eric G. Zahl, Technical Project Officer
Spokane Research Center, Spokane, Wash.

Field test sites are being designed, constructed, and analyzed near Osburn, Idaho, in the Coeur d'Alene silver mining district, to determine economically feasible and environmentally acceptable methods of mill waste disposal in flood plain areas to facilitate future land use.

In the first test site, perimeter dikes were constructed from nearby natural alluvial soils. Then, in ascending order, the following were placed: a polyvinyl chloride liner, a sand drain, a tailings slime layer, and another sand drain. These provided a means to collect water during tests to determine the contamination potential of the tailings and the effectiveness of a slime layer in draining and collecting leachates. This underdrain system was then covered with tailings and flooded to collect necessary leaching data. In addition, physical characteristics of the in-place material were tested for bearing capacities and settlement characteristics to determine the suitability of backfill areas as eventual building sites. The embankments and fill areas were also partitioned for revegetation testing to determine the most compatible vegetation cover to use until the sites reach ultimate land use. As another phase of the effort, a valley-wide mill waste disposal plan is being developed. This plan identifies flood plain locations that can be developed as waste disposal sites and presents anticipated volumes of storage and basic logistics from a district, rather than individual mine perspective.

Results of the first test indicate the following:

1. Slurry placement of tailings may be economically feasible, while dry haulage is not.
2. Generally, synthetic liners are not required for containment of contaminants.
3. Only tailings from the Bunker Hill Mine are acidic enough to leach large amounts of heavy metals from the tailings into the surrounding area.
4. Heavy metal contaminant levels in water from the test embankment are lower than the river and surrounding ground water except for lead.
5. Soil bearing capacity and settlement characteristics are acceptable for residential and light commercial development.
6. Wind erosion can be initially controlled, until vegetation is established, by gravel cover and chemical stabilizers.
7. Numerous types of vegetation are suitable with a light application of topsoil; however, irrigation is not required.
8. Approximately 23 flood plain sites could be viable for tailings disposal. These sites would provide for about 40 years of additional disposal storage and would provide an additional 750 acres for development, over half again as much as is now available.

Field test sites are being designed, constructed, and analyzed to determine economically feasible and environmentally acceptable methods of mill waste disposal in flood plain areas.

Two more test sites have been constructed and filled with slurried tailings. This will provide (1) data to determine the economic feasibility of slurried deposition, (2) further information on heavy metal and byproduct contamination potential, (3) alternatives for handling the tailings to keep contamination to acceptable levels, and (4) an updated valley-wide disposal plan.

Scraper Wheel Slip Monitor

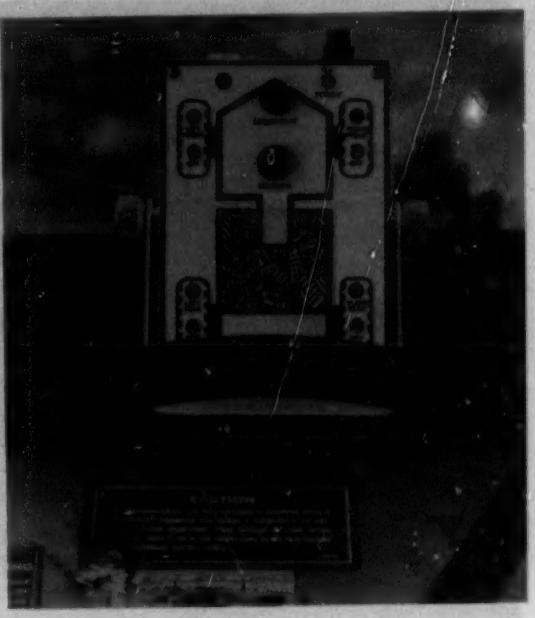
J. M. Goris, Technical Project Officer
Spokane Research Center, Spokane, Wash.

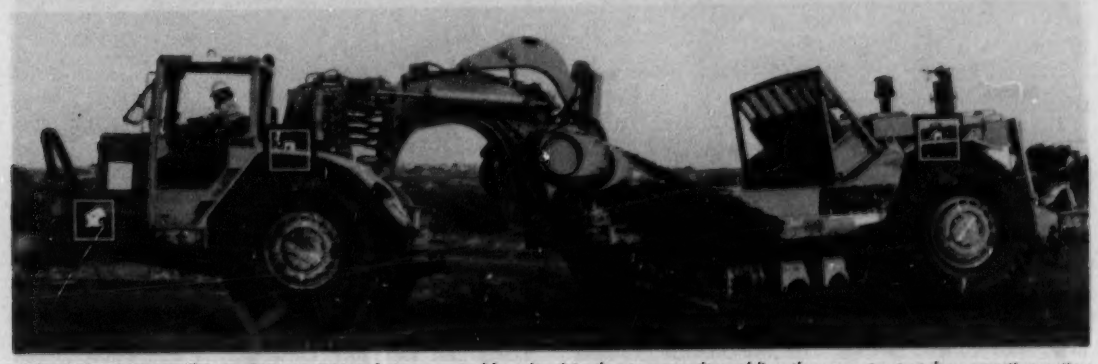
Pan scrapers represent an important tool in surface mine reclamation work. They are ideal for cutting, loading, and hauling distinct layers of material such as topsoil, as well as replacing such material in approximately the same manner in which it was removed. However, their operating costs can be high, especially if excessive wheel slippage occurs during the loading cycle. It is estimated that at least half the wear and most of the damage done to scraper tires are caused by wheel slip scrubbing during loading. In addition, wheel slippage increases loading time as well as fuel consumption.

In an effort to reduce wheel slippage, a wheel slip monitor, which senses and compares the peripheral speed of the four scraper tires to the true ground speed, has been developed. The monitor is an electronic device that is easily retrofitted to existing scrapers. It consists of five ultrasonic Doppler velocity sensing devices for measuring the velocity of each of four wheels as well as the true ground velocity. Each sensor produces an electrical

output signal whose frequency is proportional to the velocity of the tire or terrain. All of the signals are conveyed through electrical cables to a control box in the vehicle cab where they are converted to voltages proportional to individual wheel speeds. The signals are further processed to turn on one of four blinking red lights corresponding to any individual wheel that is slipping. In addition, the processed signals sound a beeping tone audible to the scraper operator. The rate of the light blinking and the tone beeping is proportional to the degree of slip. The operator, hearing the beeping tone and/or seeing the blinking light, can then take corrective action.

A prototype wheel slip monitor unit was tested using two different scrapers; the tests confirmed that the device is practical for use in mining. Since there are few, if any, scrapers on which the operator can directly see the wheels, this device can be a great aid to operators and shows promise for reducing scraper tire wear and damage. Field testing of the monitor at an active surface mine will take place during the fall of 1982.





Wheel slip monitors (bottom) transmit signals to a control box (top) in the scrapercab enabling the operator to take corrective action when slippage occurs.

Enhancing Short- and Long-Range Availability of Nitrogen and Phosphorus on Topsoil-Deficient Mine Spoil

L. M. Adams, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

It is difficult for surface mine operators in Appalachia to meet Federal requirements for the stabilization of unconsolidated overburden material. Many acres of these steep slopes usually contain only a small percentage of topsoil mixed with substrata and thus are subject to excessive soil erosion. An inadequate supply of mineral nutrients, especially nitrogen and phosphorus, limits the revegetation of mine spoil. Although short-range nutrient deficiencies in the spoil can be overcome with additions of chemical fertilizers, water infiltration limits the availability of nitrogen and phosphorus which are highly dependent upon soil moisture content. Moreover, repeated application of chemical fertilizers is costly and time consuming and it is possible that these added nutrients are not utilized to the fullest extent by the vegetative cover.

Accordingly, the Bureau has been seeking an alternative method to supply the necessary plant nutrients to the reclaimed soil.

One approach being explored is the special symbiotic relationship between the nitrogen-fixing bacteria *Rhizobia* and their host leguminous plants which may supply the required amounts of nitrogen to the soil. Numerous strains of *Rhizobia* have been isolated from the root nodules of leguminous plants (principally *Sericea lespedeza*) growing on surface mined land. Seeds were inoculated with pure cultures of the bacteria and incubated in growth chambers to determine the bacteria-host relationships that resulted in the most virile and efficient nodule-producing bacteria. Three major groups of a particular species of *Rhizobium* were isolated, which differ in their capacity to fix nitrogen efficiently. The ability of one strain to convert carbon dioxide into organic carbon—an energy source—is particularly important to *Rhizobia* survival in mine soil which is devoid of metabolizable organic carbon. The data obtained were a first for this species of *Rhizobium*. Approximately 12 pct of the isolates were capable of utilizing nitrate as an electron acceptor in place of oxygen. This ability may help to prevent the repression of nitrogenase (the enzyme system responsible for nitrogen fixation) activity. Nitrate, when assimilated, is reduced to ammonia in the plant tissue; nodule ammonia represses nitrogenase activity.

Such mechanisms may influence selection of the kind of fertilizer nitrogen to be used, particularly with respect to timing of fertilizer applications and inoculation of legumes, so that plant growth on mine soil can be maximized. Some bacterial inoculants are killed by short exposure to the widely used acid-type fertilizers, such as triple superphosphate, in the hydroseeder slurry mix. The absence of virile inoculants in the mine soil adversely affects the vegetative cover. Diammonium phosphate does not adversely influence the slurry mix acidity, but it is costlier than triple superphosphate. Field tests are being developed to determine the most cost efficient and practical organic amendment for use on surface mine spoils that will render added or residual phosphorus more available to plants for a long period.

Ecological Studies on the Revegetation Process of Surface Coal Mined Areas in North Dakota

Deborah P. Sherer, Technical Project Officer
Denver Research Center, Denver, Colo.

The Bureau has been conducting surface coal mining reclamation research on North Dakota lignite properties since 1975. The objective of these long-term studies has been to conduct basic research on surface mine restoration ecology in order to better understand how disturbed lands repair themselves with and without human intervention. The range of this research has been very broad encompassing topics such as microbiological investigations of abandoned spoils, plant growth response to a variety of amendments, plant succession on abandoned and reclaimed spoils, chemical and physical analyses of abandoned and reclaimed spoils, controlled environment experimentation on the effects of limiting plant nutrients, and determination of aquatic organism diversity and water chemistry of catch basins.

The results of this research have yielded the following recommendations:

1. Analysis of spoil materials shows them to be highly variable in chemical and physical properties; these properties almost universally need to be enhanced by fertilization.
2. Topsoil spreading appears to be the most effective reclamation practice.
3. Lignitic materials like leonardite should be carefully analyzed before using to ameliorate spoil properties; they are not recommended for use on saline and/or sodic spoils.
4. Phosphorus application should be in low dosages as high levels may inhibit natural processes involved in making indigenous phosphorus available.
5. Nitrogen fertilization enhances grass growth in particular.
6. The inclusion of manganese and zinc enhances plant growth when fertilizing spoils.
7. An alternative to amending spoils is the identification of salt-tolerant, phosphorus-efficient, drought-hardy plant species.
8. Topographic features such as slope exposure and position should be considered in species growth performance.
9. The initial weedy stage on top soiled areas provides an important nurse crop and should not be eliminated by herbicides.
10. Plant cover and biomass production were found to correlate significantly on grass-forb vegetation which could eliminate the need for destructive sampling of biomass.
11. The top 3 to 4 in of topsoil contains the maximum seed diversity and abundance and the highest organic matter content. Consideration should be given to segregation of this layer.

Soil Depth Requirements for Surface Mine Reclamation in the Northern Great Plains

Deborah P. Sherer, Technical Project Officer
Denver Mining Research Center, Denver, Colo.

A 5-year study of 14 field plots established at active coal mine sites in the Northern Great Plains Coal Province has been completed. The objective of the study was to determine soil depth requirements for reclamation. The study data reflect biomass response patterns found on four differing spoil types ranging from sodic and fine-textured to strongly acid in composition with varying amounts of topsoil cover and precipitation. Soil depth over these spoil types ranged from zero to about 5 ft.

Spoil described as neutral, nonsaline, nonsodic clay loam provided optimum percentage cover when topsoil was 10 in or more deep. Depending upon precipitation and individual plant species, the topsoil requirement for maximum productivity was more than 3 ft for this spoil type.

A second type of spoil was described as sodic, moderately to highly alkaline, silty or clayey loam with swelling clays being dominant. Soil depth for optimum cover was only about 2 in for this type of spoil but soil depth required for optimum production was in excess of 30 in. Without some soil cover, this spoil type supported almost no growth of any kind.

The third type of spoil was acidic with an average pH of 4.0. Heavy metals and carbonaceous material ranging from 1 to 20 pct were present in this spoil. The study found that subsurface acidification was limited to the basal 4 in of soil cover over this spoil and that, as soil depth increased, the yield of perennial grasses appeared to increase also in a linear fashion. The data indicate that optimum yields would occur with soil depths exceeding 5 ft.

A fourth type of spoil tested resembled soil in that it was neutral in pH, nonsaline, nonsodic, and contained only minor amounts of carbonaceous material. Plant production and cover showed no response to increasing soil depth over this type of spoil. From this it appears that this type of spoil, where found, is equal to soil in its productive capacity.

Plant quality was measured for growth occurring in soil and in spoil. The material grown in spoil

Vegetation test plots were used to determine soil requirements for surface mine reclamation in the northern Great Plains.

had lower levels of phosphorus, some slight enhancement of heavy metals and, in the third spoil type, an elevated level of selenium. The selenium level was about 50 pct of the level considered toxic in forage. Microbial activity was, as expected, quite low in spoil material but increased substantially when soil cover was added. In some situations, the microbial community appeared to be more closely related to the density of plant cover than to plant production. In the third spoil type (highly acidic), microbial activity did not attain an optimum level and appeared to parallel plant production.

Since establishment of a selfsustaining vegetative community is the primary goal of reclamation, the soil depth required to attain this goal is a key factor in determining the costs of a given reclamation effort. This study establishes the fact that rigid, uniform regulations requiring standard soil depths may be counterproductive.

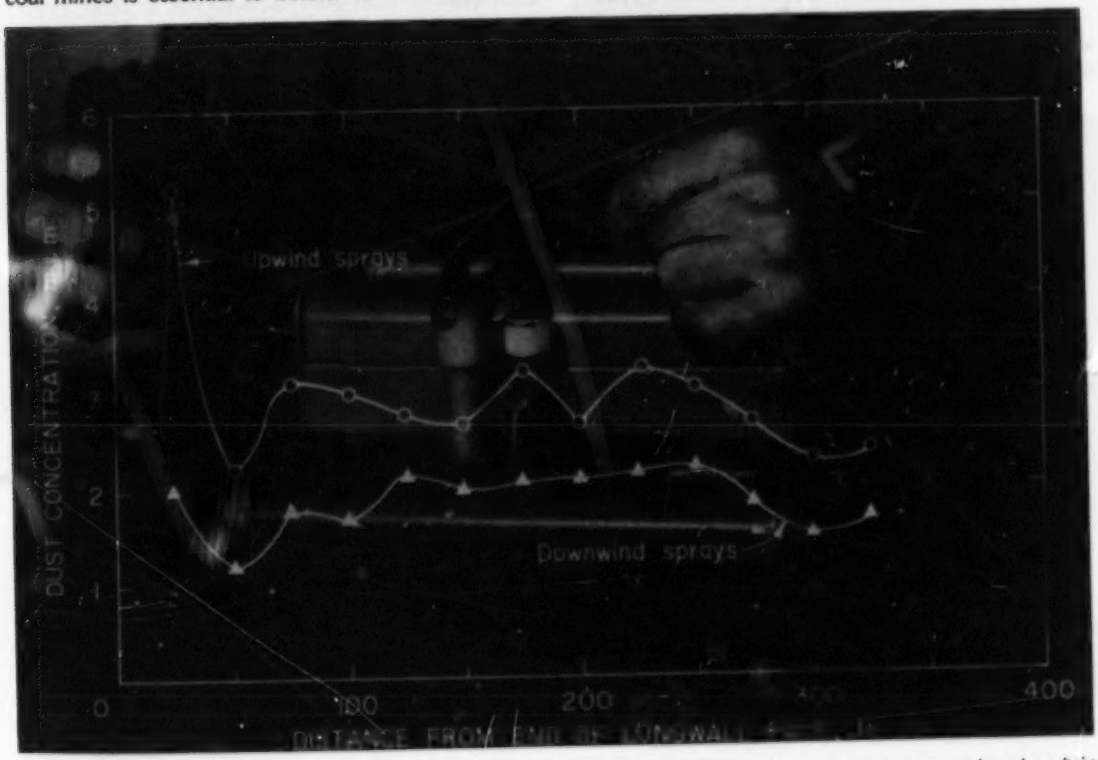
Health and Safety Technology

Respirable Dust

Improved Sampling Techniques Aid Dust Control Research

C. D. Taylor, R. A. Jankowski, and S. J. Page, Principal Investigators
Pittsburgh, Research Center, Pittsburgh, Pa.

Sampling of respirable dust in underground coal mines is essential to determine the effectiveness of the dust control technologies being implemented and to identify areas requiring further research. Because dust concentrations vary greatly during an 8-hr working shift, most dust control procedures must be evaluated by short-term sampling methods (usually less than 4 hr). Two techniques are currently used for reliable, accurate sampling of airborne mine dust. Gravimetric sampling is a well-established procedure whose



Immediate dust concentration readout is possible with a recently developed continuous dust sampling instrument based on light scattering by dust particles.

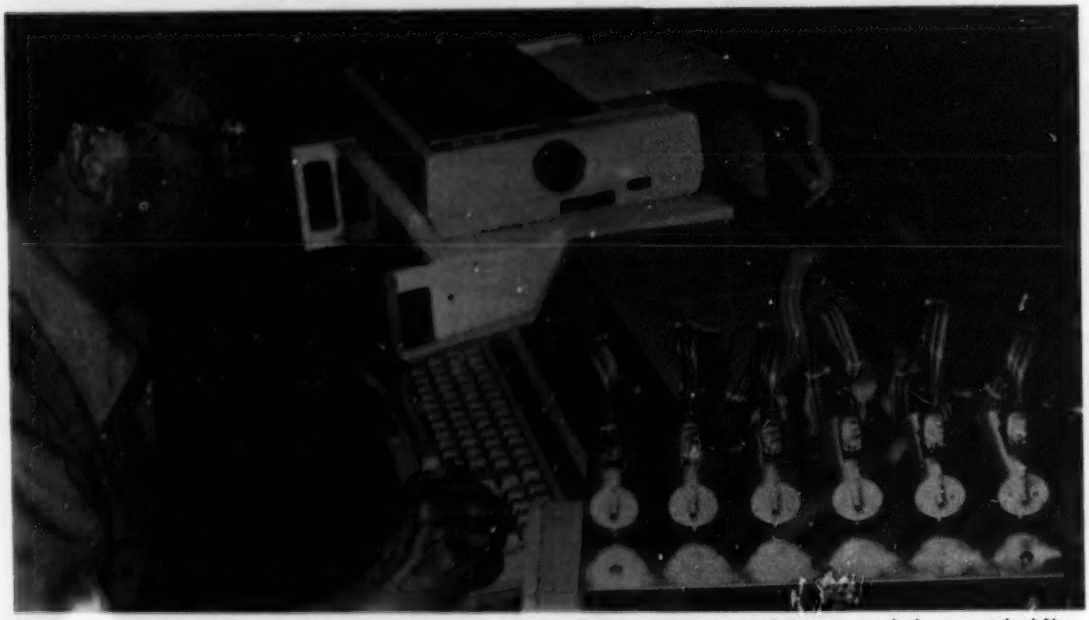
usefulness has been improved through the development of weighing techniques that give accurate data for sample filters with low dust masses. The gravimetric method can be used for mobile and stationary sampling, with the simultaneous use of two to four samplers giving added precision and helping to identify bad samples. However, gravimetric sampling requires an analytical laboratory, with an inevitable delay in data interpretation. Immediate readout is possible with a recently developed continuous dust sampling instrument based on light scattering by dust particles. The dust concentrations are read out directly and can be stored in hand-held tape recorders, together with related information.

On longwalls, two persons each carrying one of the new continuous samplers can simultaneously measure dust levels at the shearer midpoint and immediately upwind of the shearer. This type of sampling has shown that worker exposure can vary greatly along the face and that cutting conditions (rock band, rock bottom) can increase face dust levels significantly. In addition, during the cutting sequence upwind, dust sources such as support movement, may be the primary cause of shearer operator dust exposure. Dust profiles for the work area near the shearer were obtained by measuring dust levels with the continuous sampler at a fixed position in the face walkway, as the shearer approached and passed this position. These profiles show that dust levels increase greatly from the intake to the return-air side of the shearer, and therefore that worker location can be an important factor in individual dust exposure.

New Approaches for Personal Dust Exposure Monitoring

R. P. Vinson and K. L. Williams, Principal Investigators
Pittsburgh Research Center, Pittsburgh, Pa.

Prevention of coal miner pneumoconiosis (black lung) requires instruments that provide reliable information on miner exposure to respirable dust. Two personal respirable dust monitors being developed by the Bureau are undergoing final lab evaluation. The first is a small, lightweight, belt-worn device, that measures the light scattered by the dust that enters its detection chamber by natural airflow. It routinely displays the current dust level immediately surrounding the wearer. Upon command, it will also display the current shift average exposure, or the shift average of the most recent seven shifts. A semiconductor infrared source provides the light; scattering is detected by a



New personal respirable dust monitors utilize a tapered element, oscillating membrane microbalance instead of a preweighed filter. Readout is automatic and can be attached to a computer-based recordkeeping system.

photodetector. An internal clock and custom-made calculator integrated circuit are used to compute the shift average and store the individual averages of the previous seven shifts of operation. Because light scattering of dust is not uniquely related to its mass, to provide an accurate indication of actual dust concentrations the device must be calibrated against a gravimetric sampler simultaneously exposed to the same dust concentration. Without such calibration, it is still a very good indicator of relative changes in dust levels and hence, can also be used to define areas of high dust levels or to locate dust sources.

The second device for measuring personal dust exposure, known as the TEOM, uses a tapered element oscillating microbalance. It consists of a hollow glass pedestal that supports a filter. When the glass pedestal vibrates, it does so at a frequency that depends upon the mass of the filter. The TEOM filter unit is compatible with the coal mine dust personal sampler units now used by MSHA (Mine Safety and Health Administration) and mine operators, which consist of a pump, a preweighed filter, and a cyclone-size selection device. The pump pulls the dusty mine air through the cyclone and the filter at a rate of a 1 liter per minute. The weight gain of the filter, the sampling time, and the flow rate are used to calculate the average dust concentration. The TEOM assembly is designed to replace the preweighed filter. The mass gain of the TEOM filter is evaluated by attaching the TEOM assembly to a readout console that excites the pedestal to vibration, removes water from the filter, and measures the pedestal vibration frequency. The TEOM filter can be used for many samplings. The TEOM assembly has several advantages over the present preweighed dust filter cassette. Readout is automatic and eliminates weighing errors. Results can be obtained shortly after the end of the sampling period and even at the mine site. The TEOM readout system can be automated and attached to a computer-based recordkeeping system; each TEOM assembly can be uniquely numbered and the mass gain data, date, shift time, and location data entered by hand, recorded against the TEOM assembly number.

Conveyor Belt Dust Control

Richard J. Wilson, Technical Project Officer
Twin Cities Research Center, Minneapolis, Minn.

The problem of respirable dust generation at conveyor belt transfer points is well known. Application of effective dust control technologies

Conveyor belt dust generation (left) is controlled by a dry vacuum dust collection system (right). The prototype system is one of two undergoing long-term testing under a variety of environmental conditions.

has not occurred because conveyor haulage systems require demanding performance characteristics that preclude the simple adaptation of dust control methods from other mineral industry applications. Among the more severe complicating factors is the wide range of environmental conditions under which conveyor systems operate. Conveyor belts run all year round in the harshest climates, thus necessitating dust control technologies that are effective in wet, dry, frigid, and hot environments. A second factor is that conveyors operate continuously in many installations, thus making reliability of the utmost importance for any equipment that is to be utilized.

Two prototype dust control systems designed to satisfy these requirements have been fabricated and installed at a limestone quarry near Baltimore, Md., for a 1-year test. The two systems are based on dry vacuum collection and water mist suppression technologies respectively. They have been applied at a variety of transfer points including primary crusher to belt, belt to belt, and tertiary crusher to belt. An effort is underway to include vibrating screen to belt transfer points within the program.

The field test will determine the long-term effectiveness and reliability of the two prototype systems under a variety of environmental conditions. An extensive dust sampling program using gravimetric samplers is yielding dust concentration data that will, over the course of the test period, allow optimization of the airflow rates and water mist droplet size and concentration. Guidelines for the effective application of these dust control systems will be made available to the industry following completion of the tests.

Improved Water Spray System for Continuous Miner Dust Control

N. I. Jayaraman, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

The introduction of continuous mining machines in U.S. coal mines has improved productivity, but increased health hazards due to the large amounts of respirable dust generated during cutting. To alleviate this condition, the Bureau is developing dust control technology for room-and-pillar mining, based on the use of the machine-mounted water sprays that have proved so effective in other recent applications. Trials with a full scale model of a continuous miner operating in a room-and-pillar section and equipped with various water spray systems have shown that—

1. To be effective, water sprays must sweep the air along the natural ventilation path, that is, around the continuous miner and into the air return; any spray arrangement that short circuits the air away from this path causes dust rollback at the operator position.

2. Certain spray combinations increase the rate at which respirable dust is exhausted to the air return; a spray mounted in a conventional side position and aimed at the return, gave good results in low coal (4-ft seam).

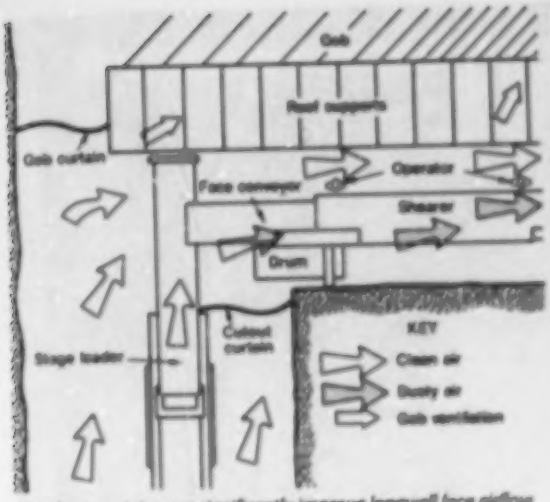
3. Nozzles vary significantly in dust knockdown capability. Hollow-cone nozzles are among the most effective; peak dust knockdown efficiencies are obtained at pressures of less than 100 psi (pounds per square inch).

Underground testing of a spray-equipped continuous miner has begun in one mine where the line brattice is usually kept at a 10-ft distance from the face. Preliminary results obtained with exhaust face ventilation indicate that timing and interrelation of face operations (shuttle car traffic, irregular cutting and loading sequences), have a considerable effect on operator exposure, regardless of the spray system employed.

Advances in Longwall Dust Control

F. N. Kissell, R. A. Jankowski, N. I. Jayaraman, and C. D. Taylor, Principal Investigators
Pittsburgh Research Center, Pittsburgh, Pa.

Adequate amounts of clean air must be provided to longwall shearer faces to dilute and carry the airborne respirable dust down the face and prevent dust migration out into the walkway. Coursing the primary airflow in the same direction as coal transport (tail to head) can significantly reduce the amount of dust generated by coal transport and secondary crushing in the headgate, but tail-to-head ventilation requires keeping the tailgate entries open. On longwalls where roof pressures associated with extracted adjacent panels tend to create roof falls in tailgate entries, tail-to-head ventilation is not feasible. On longwall faces with conventional ventilation, a water-powered scrubber, installed over the stage loader in the headgate entry, can reduce intake dust levels. The scrubber is mounted immediately outby the crusher and the scrubber intake is ducted over the crusher discharge. Dusty air is drawn from the crusher, through the scrubber, where it is cleaned by water sprays and discharged back into the primary airflow. Underground evaluations have



Headgate curtains can significantly improve longwall face airflow and lower face workers' respirable dust exposures.

shown that this system can reduce intake dust levels by approximately 50 pct.

Brattice curtains in the headgate entry can also be used to improve dust control on longwalls. A "gob" curtain hung between the No. 1 shield and the rib in the headgate entry forces the ventilating air stream to make the 90° turn, staying on the face side of the shields rather than leaking into the gob; this can increase average face airflow about 35 pct. A "cut-out" curtain, installed between the stage loader and the panel side rib, directs the primary airflow out and around the shearer drum as it cuts out into the headgate entry; this prevents the high velocity airflow from passing over and through the drum to carry the dust into the walkway and over the shearer operators.

Approximately one-third of U.S. longwalls operating with double-drum shearer use a version of the Bureau's shearer clearer system. Methods for maintaining the split of clean air adjacent to, and on the return air side of the shearer are being improved. A study of the six least dusty longwalls has shown that these operations use higher than normal waterflow rates, primarily to the cutting drums and a system is being developed to automatically proportion higher amounts of the shearer water supply to the upwind drum. The selection of the proper nozzle type is important. Hollow-cone nozzles provide the best use of water for dust knockdown. They move reasonable amounts of air at moderate pressures (100-150 psig (pounds per square inch, gage)), have less tendency to clog, and require lower waterflow rates than other nozzle types, at a given operating pressure.

A study of the six longwalls with much better than average dust compliance records indicates that machine design and cutting sequence can be modified to effectively reduce the amount of dust produced as well as the respirable dust exposure of most longwall face workers. At one mine, a modified unidirectional cutting sequence places the primary dust source, the cutting action of the drums, on the return air side of both shearer operators. During the head-to-tail cut, the trailing drum is "free wheeling," cutting minimal bottom coal; during the tail-to-head cut, the trailing drum cuts the remaining bench of bottom coal. Enhanced dust control is obtained on a bidirectional double-drum shearer that is equipped with two different diameter cutting drums. A 60-in return-air side drum cuts the entire coal seam when cutting with the airflow; a 47-in intake-air side drum cuts the middle of the coal seam when cutting against the airflow, while the larger drum trims the roof and floor coal.

Radiation Hazards

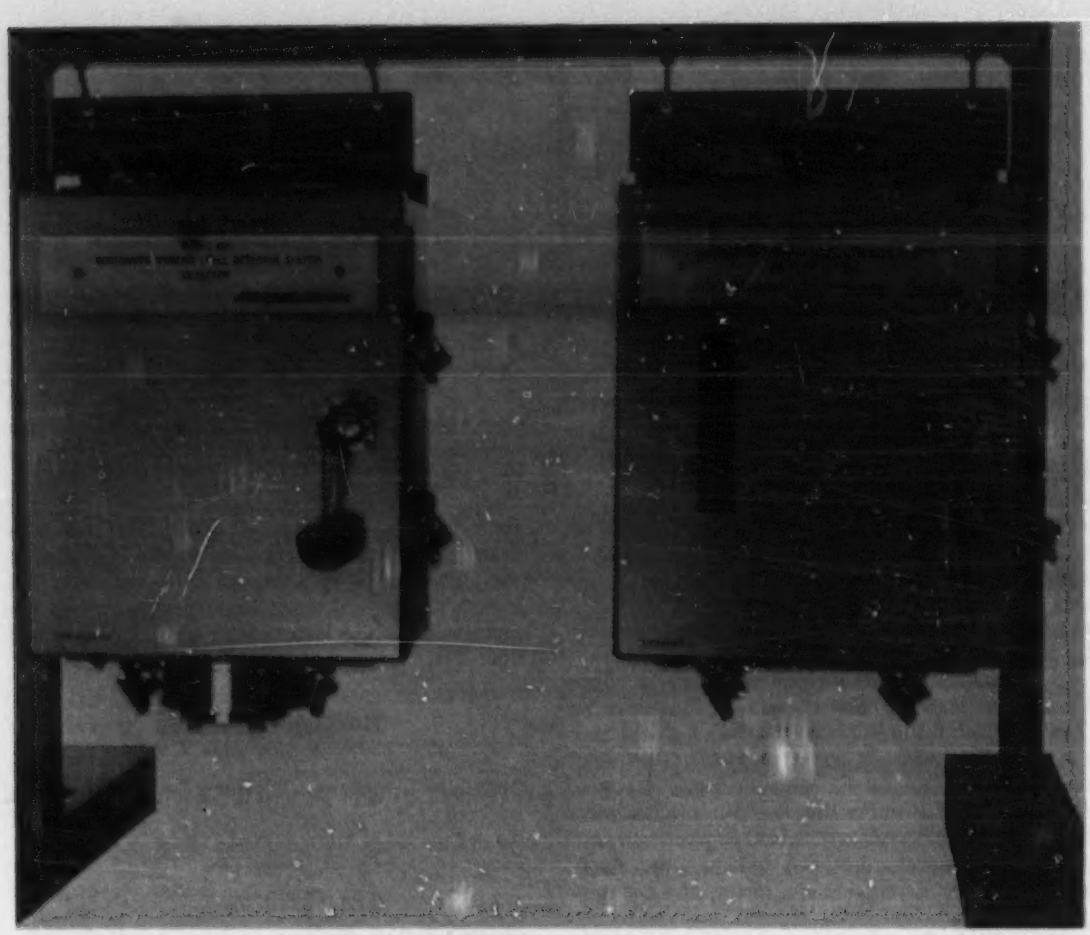
Improved Continuous Working Level Monitoring System

Robert F. Droullard, Technical Project Officer
Denver Research Center, Denver, Colo.

An improved continuous working level monitoring system has been developed by the Bureau. The ionizing radiation detector portion of this system is based on previously developed Bureau method for continuously measuring beta activity collected on a filter paper and relating this information to working level exposure units.

The new system employs two housings; one for the radiation detector and its signal processing electronics and one for the continuous air system. Improvements over previous continuous working level detector systems include increased sensitivity, minimum resolving time losses, and an air pump with a battery power supply that permits air sampling during short-term power failures.

This continuous exposure monitor will provide industry with a way to measure average concentration of radon daughter activity at selected underground sites. When connected to appropriate signal processing system, the monitor will activate alarms when ionizing radiation exposure levels exceed predetermined values. All of the necessary equip-



An improved radiation exposure monitor can also be connected to appropriate signal processing systems to activate alarms when ionizing radiation exposure levels exceed predetermined values.

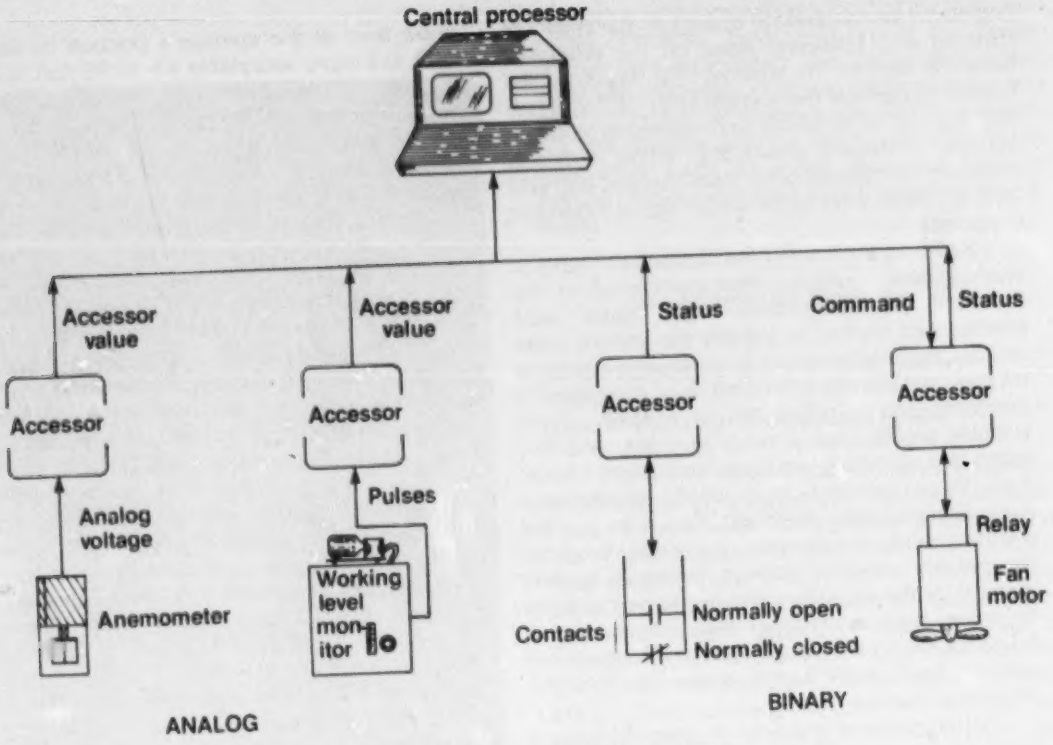
ment for a mine monitoring system is available from commercial sources.

Computerized Radiation Monitoring and Control System

John C. Franklin, Principal Investigator
Spokane Research Center, Spokane, Wash.

A commercially available, real-time, microprocessor-based system capable of monitoring and controlling 600 channels has been interfaced with monitors for radon, working level, air velocity, and fan power. The system consists of a desktop terminal and printer, a communication trunk, and accessors. The accessors interface to the various field devices to be monitored or controlled and connect to the trunk via a common-shielded four-conductor cable. Up to four trunks may be used with the system, and up to 128 accessors may be used per trunk. Accessors may be wired in series, parallel, or branched from the trunkline for installation in different parts of the mine.

There are two basic types of accessors that can be used—binary and analog. Binary accessors may be used to monitor or control ventilation fans or to sense the position of air doors. Analog accessors report readings from various field devices such as radiation monitors, pressure monitors, or anemometers. These readings are converted to engineering units by the processor for display and printout. Each accessor is actually a point multiplexer with its own unique address and identity.



Block diagram of a computerized radiation alarm system.

All alarms and changes of state are automatically displayed and printed out. Types of alarms possible include communication failure; high, low, and rate alarms for analog accessors; and on, off, and sensor line fault alarms for binary accessors.

Shift report (averaged reading) and trend log (point reading) printouts may be requested by the operator for analog points to monitor changes over a period of time. Also, up to six points may be entered on the CRT screen for continuous updating, and an immediate status report can be requested for any point in the system.

A software feature permits the operator to program control sequences that may then be started manually or automatically. These sequences have been used to automatically restart fans with time delays after a power failure.

This system, as interfaced for uranium mining operations, will alert ventilation personnel to rapidly changing radiation conditions as well as to ventilation problems before critical working levels are reached. The recordkeeping aspects of the system may be used to engineering studies to aid in increasing ventilation effectiveness and also to keep track of average radon-daughter exposure for monitor locations. The sequencing may be used to alert underground personnel to alarm conditions by sounding a horn or flashing a light.

This system is now undergoing extensive field testing in an active unranium mine. It has been successfully used to control and monitor fans and to report airborne radiation concentrations from continuous working level monitors.

Noise Control

Retrofit Noise Control Techniques for the Crushing and Screening of Nonmetallic Minerals

T. G. Bobick, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Many of the workers in nonmetal crushing and screening plants have full shift noise exposures that exceed federally established limits. Because some 12,000 portable and stationary nonmetallic proces-

sing plants are currently in operation, the impact of crushing and screening noise on the employee health is severe. To alleviate this situation, the Bureau undertook the identification of the prevalent sources of crushing and screening noise in portable processing plants, the design of retrofit noise control treatments for those sources, and field tests of these treatments under actual operating conditions.

Based on a survey of the number and types of crushing and screening equipment used in the nonmetal mining industry, eight plants were selected and studied to identify the various noise sources, determine worker noise exposure to those sources, and identify constraints to be considered in designing and installing retrofit controls. Three portable plants (one primary crushing, and two secondary screening and crushing) were chosen from those surveyed, and retrofit modifications were designed and installed. The noise control treatments included an operator's control booth for the primary crusher; decking made of resilient material for the secondary screens; impact pads for the screen feedbox; a rubber feed plate and rubber linings for the feed chute for both of the secondary crushers; and a noise barrier curtain for one of the secondary crushers.

At the primary crusher, an operator control booth produced a 17-dbA (decibels, A-weighted network) reduction (95 to 78 dbA), at a cost of approximately $6,000. For the two secondary crushing and screening plants, the cleanup and maintenance work areas averaged 5 to 6 dbA reduction (98 to 92-93 dbA) at both plants; total material and installation costs were about $15,000 at one plant and about $16,000 for the other. A handbook is planned for use in selecting and installing noise control materials.

Integration of Noise Control Technology Into Load-Haul-Dump Machines

T. G. Bobick, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

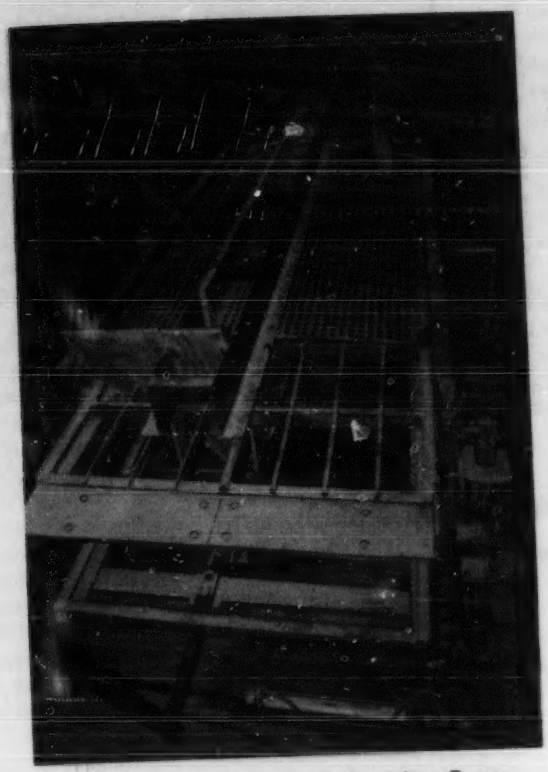
An earlier Bureau survey identified the diesel-powered load-haul-dump (LHD) machine as a major contributor to the noise exposure of underground metal-nonmetal miners, not only because it generates high noise levels, typically 100 to 102 dbA (decibels, A-weighted network) at the operator's location, but also because of the large number of these machines in use. Subsequent research by the Bureau on a popular LHD model showed that retrofit noise controls reduced the noise level at the operator's position by about 7 dbA to a more acceptable 93- to 95-dbA level.

Although application of noise control materials to vehicles that are already in operation is feasible and practical, installing noise controls during manufacture of the machines is a better long-term solution. Noise controls that are designed into the equipment, instead of being added on to existing equipment, will be more cost effective and will be more readily accepted by the industry. To establish the value of this latter concept, the Bureau selected two different models of LHD equipment (a 2- and an 8-yd^3 (cubic yard) bucket), to be noise controlled as they were built. Baseline measurements were made in an appropriate environment on the unmodified machines. Each machine was then disassembled to a point where vibration mounts could be installed on the transmission; other control materials were installed at the engine and operator compartments, and at other areas diagnosed as important secondary noise sources. Evaluation of the modified machines showed that for the 8-yd^3 LHD, noise reduction at the operator's position was more than 9 dbA, from 99.0 to 89.7 dbA; for the 2-yd^3 machine it was better than 10 dbA, from 101.1 to 90.8 dbA. After the two LHD's are in used underground, followup surveys will be conducted for 1 year to observe the effectiveness and durability of the factory-integrated treatment in a working mine.

Computer Modeling of Nonmetallic Screen Deck Performance

T. G. Bobick, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Noise levels generated by vibrating sizing screens typically range from 95 to 105 dbA (decibels, A-weighted network) for a normal multiple-screen operation and are due primarily to two causes—impact of the material against the metal decks, the sidewalls, and the discharge lip; and operation of the drive mechanism. Replacing the metal deck with a deck made of rubber or another resilient material reduces the severity of the metal-material impacts, and hence the associated noise. Nonmetallic decks are being used more frequently on vibrating screens because of their lower noise levels and longer wear, as compared with conventional metal decks. However, information to predict the screening efficiency of a given resilient material is lacking. Before resilient materials are used routinely, their screening performance must be defined more accurately. To assist



Controlled laboratory testing has shown that a Bureau simulation model can predict separation efficiency within ±2 pct of measured values. The model can be used to predict the screening efficiency of resilient-material decks used to replace metal decks for noise control.

plant operators in modifying their screening decking, the Bureau has developed a digital computer model that simulates the screening process for a variety of operating conditions, such as feed rate, deck type and deck opening geometry, angle of particle approach, and particle size distribution.

The model utilizes mathematical expressions to describe the probability of a certain size particle passing through a certain size opening for a single opportunity; the total number of opportunities that the particles have to pass through the deck as they flow along; and the effects of the depth of material on screening performance (efficiency can vary with the amount of material fed onto the screen). Screening tests under controlled laboratory conditions showed that the simulation model can predict separation efficiency within ±2 pct of the measured values. Predicted sieve analyses of the underproduct and overproduct also are in good agreement with laboratory analyses. Information on how much screening performance will vary for a specific resilient material will be made available in an application guide to assist plant managers in making changes that meet their processing requirements.

Industrial Hygiene

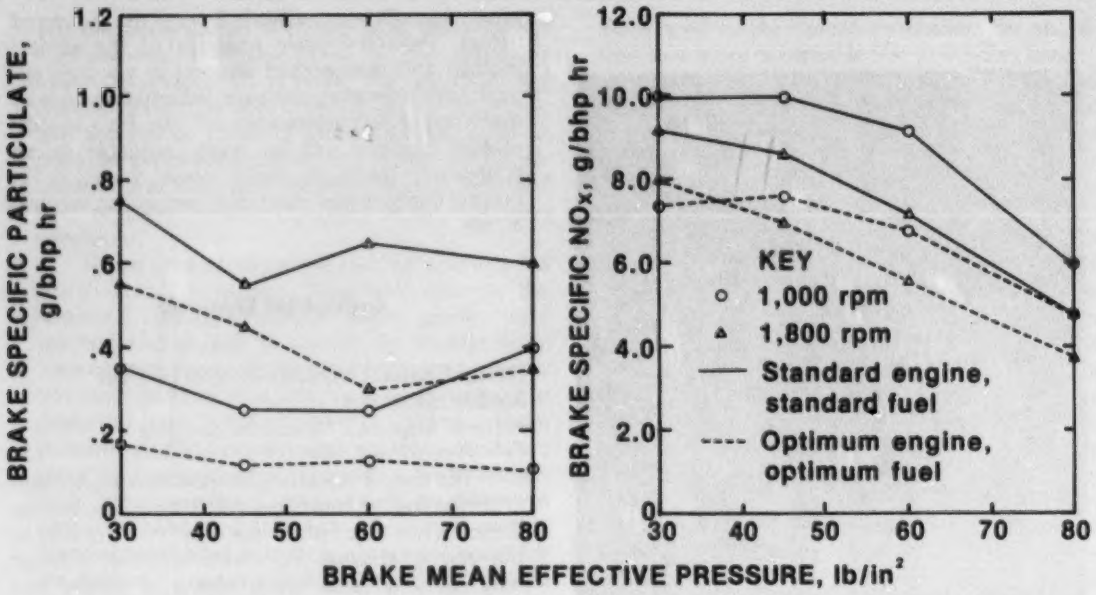
Diesel Engine Emission Control by Fuel Modification

Robert W. Waytulonis, Technical Project Officer
Twin Cities Research Center, Minneapolis, Minn.

The use of diesel-engine-powered equipment is increasing in underground mining operations. Concern has arisen about the effect on air quality of the engine exhaust. Pollutants in diesel exhaust may cause adverse health effects in miners and must be controlled to minimize exposures. Such pollutants include particulate matter, oxides of nitrogen (NO_x or NO and NO_2), hydrocarbons (HC), carbon monoxide (CO), and oxides of sulfur (SO_x). These pollutants are controlled to prescribed levels in ambient air primarily with ventilation, but the most efficient control strategy is removal of pollutants from the engine exhaust.

The Bureau has a research program to develop emission controls for diesel engines. In this program is an investigation that evaluates the effect of using a modified fuel on the chemical and physical characteristics of diesel exhaust. Interest in the effect of fuel composition upon diesel exhaust is based on the need to decrease the two pollutants presently of most concern—particulate matter and NO_x. Emission control through fuel modification is a favorable approach for mine diesels since it precludes more complex mechanical methods such as engine modifications or exhaust aftertreatment; however, using such a fuel adds to the already difficult mine production and maintenance operations. Current work is determining whether the use of a modified fuel will reduce the emissions of concern. The goal is the reduction of particulate matter and NO_x without significant increases in either HC or CO. The SO_x in the exhaust can be minimized by limiting the sulfur content of the modified fuel.

Fuels and fuel blends that were evaluated included DF-1, DF-2, and JP-7; a solution and an



Diesel engine and fuel modification effects on particulate and NO_x emissions with varying brake mean effective pressure.

emulsion of ethanol with DF-2; emulsions and fumigation of water with DF-2; and LPG (liquified petroleum gas) with DF-2 pilot injection. All emission testing was performed on an engine that is used in many types of mining equipment. After extensive testing, a stabilized microemulsion of water in DF-2 proved to be the most promising fuel. This was based upon significant reductions of particulate matter and NO_x, availability, and the inherent fire-safe characteristics of the fuel. In this microemulsion fuel, submicron droplets of water are held in stable suspension in DF-2 fuel by the action of a liquid surfactant.

The fuel and engine were then parametrically optimized to gain maximum particulate matter and NO_x reductions. For the fuel, this optimization involved determining the most efficient quantity of water and surfactant. The engine configuration was optimized by altering the compression ratio and injection timing to take full advantage of the combustion characteristics of the microemulsion fuel. Steady-state emissions tests of the optimized engine-fuel system showed that particulate matter was reduced 35 to 53 pct. These values are the average percent change over the entire load range at 1,800 and 1,000 rpm (revolutions per minute) respectively.

Although these reductions are significant, they were observed at steady-state engine conditions, which is an accepted test procedure to quantify changes in emissions resulting from experimental work. To date, steady-state emission testing has been performed to measure the characteristics of engine exhaust, but the correlation between steady-state procedures and actual in-service duty-cycle behavior is very poor. This means that the steady-state results may not accurately reflect engine emissions under actual operating conditions. For example, tests performed by the Environmental Protection Agency have shown that it is possible to design an exhuast aftertreatment system that appears to reduce engine emissions to negligible levels on the steady-state tests and at the same time provide little or no emission reduction under transient conditions. A transient test is a remedy to this concern because it approximates in-use engine performance.

The optimized engine-fuel system is currently undergoing verification testing using a transient test procedure. The system will be linked to a dynamometer to either absorb the engine energy and apply a load or to drive the engine (this simulates braking or "motoring"). By controlling the dynamometer, the engine can be subjected to conditions that simulate the operation of an engine in service.

Monitoring Mine Air Pollutants

G. H. Schnackenberg, Jr., Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Use of diesel-powered vehicles in underground mines can increase economy, safety, and productivity, but the exhaust from diesel engines contains substances that can be toxic or irritating if present in excessive quantities. Maintaining an acceptable air quality in dieselized underground mines is one goal of Bureau research. To accomplish this goal, the relationship among the diesel vehicle, its emissions, and its operating environment is being studied.

In most room-and-pillar noncoal mines, the highest level of diesel activity with the least ventilation occurs near the face, in the mucking operations that remove the ore. To study these so-called dead end drift operations and areas, a test facility has been set up at the White Pine (Mich.) copper mine. The facility consists of a variable length dead end drift with a diesel-powered scoop tram that has been equipped to record vehicle and engine operating parameters and CO_2 levels near the operator. The facility also has a monitoring laboratory that measures NO, NO_2, CO, and CO_2, particulate matter, temperatures, and air velocities at several fixed points in the test drift. Experiments in this test facility have shown that CO_2, as well as other substances in the diesel exhaust, can be reduced by half if the exhaust is directed rearward toward the roof at 30° from the horizontal, rather than directed out the side of the machine near the mine floor as is customary with scoop trams. Emission control devices consisting of a catalytic converter and a fiberglass-stainless steel woven mesh particulate trap were evaluated with No. 1 and 2 diesel fuels. It was found that with No. 2 fuel, catalysts should be removed to prevent the increased particulate caused by the catalytic action on the higher sulfur levels of No. 2 fuel. The particulate trap reduced about 50 pct of the diesel soot emitted.

Based on analysis of diesel emissions and on a computer simulation model, there appears to be a definite correlation between diesel engine emissions of CO_2 and of other gases and particulates, especially in dead end drifts where a single vehicle is operating. The computer model also predicts excellent correlation between CO_2 and an air quality or ventilation index, developed by the Canadian Centre for Mineral and Energy Technology, that combines the ratios of all pollutant concentrations with their individual acceptable levels into a single number. Thus, CO_2 may be a particularly good indicator of overall air quality near diesels. Current efforts are concentrating on developing the emission measurement apparatus and in defining those air quality measurements and techniques than can be used by mine operators to support and supplement CO_2 as the basic indicator of mine air quality.

Products of Thermal Degradation of Mine Materials

T. Christos, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

The Bureau is concerned that certain materials used in underground mines could produce toxic combustion products in case of a mine fire. To evaluate toxicity hazards, thermal degradation studies are being conducted on conveyor belts and their components (basic polymers, fibers, additives, flame retardants, plasticizers, preservatives); solvents and fire extinguishants; hydraulic fluids; treated and untreated woods; and miscellaneous compositions. In particular, there is considerable interest in the elastomers and other polymers used in noise and vibration treatments of mining equipment.

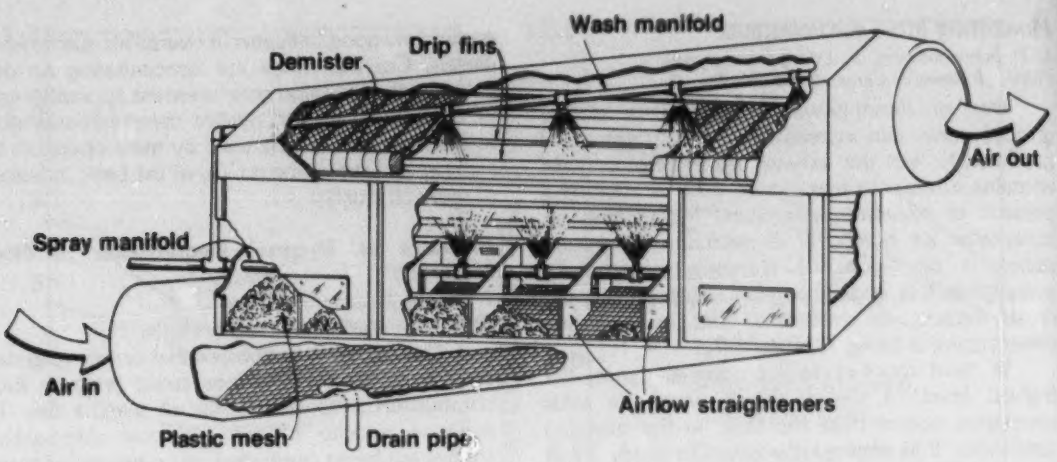
Thermal oxidative degradation was studied under dynamic conditions in an apparatus capable of simulating different temperatures, air flows, and atmospheres, as well as accommodating samples of different thickness, and permitting total and intermittent sampling of evolved products. Sample and gas temperatures, smoke density, and concentrations of oxygen, carbon monoxide, and carbon dioxide concentrations were monitored continuously. The volatiles liberated were presented in tables showing milligrams of specific product per gram weight loss of sample being heated. To provide a summary value for the total potential toxic hazard of a material, the results were compiled in a table on the basis of weight loss (mg/g) and area-time ($mg/in^2 \cdot min^{-1}$) factors for the major toxic species evolved from each material. On a relative basis, dimethyl silicone was found to present the least toxic hazard of the elastomers examined; one flame resistant styrene-butadiene rubber presented the greatest (relative hazard).

Ventilation

Water Spray Cooler

E. D. Thimons, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

As working levels in U.S. metal and nonmetal mines descend to greater depths, mine operators



A spray cooler system has been developed for deep metal and nonmetal mines where temperatures can reach 130° F.

must deal with the problems of hot working environments. Several major mines are already operating at depths where the virgin rock temperatures are in the range of 130° F. The energy and maintenance costs associated with operating refrigeration equipment in these mines represent a substantial portion of the total overhead.

To meet the need for efficient, low-maintenance cooling equipment, the Bureau has developed a water spray cooler that provides direct air-to-water heat exchange and is specifically designed to cool the hot working areas of deep mines. The incoming air passes through a bottom pad of plastic- or wire-mesh. Here it is exposed to water, flowing downward through the pad to the water sump, which has fallen from the sprays or dripped from the upper wire-mesh mist eliminator. Next, the air passes through the chilled water sprays and the water dripping from the mist eliminator. Finally, it is cooled further as it passes through the upper wire-mesh demister pad, which holds some of the spray water before allowing it to drip to the bottom of the cooler. At each of the cooling stages, heat is exchanged by direct contact between the warm mine ventilation air and the cooler water from the mine's chilled water supply.

In trials at the Homestake (S. Dak.) gold mine, the water spray cooler outperformed conventional finned-coil coolers. It requires little maintenance, whereas the finned-coil coolers require dust removal every 2 weeks. Currently, some 40 spray coolers are in routine operation at the Homestake Mine and larger scale water spray coolers are being designed for use in a uranium mine in Mexico.

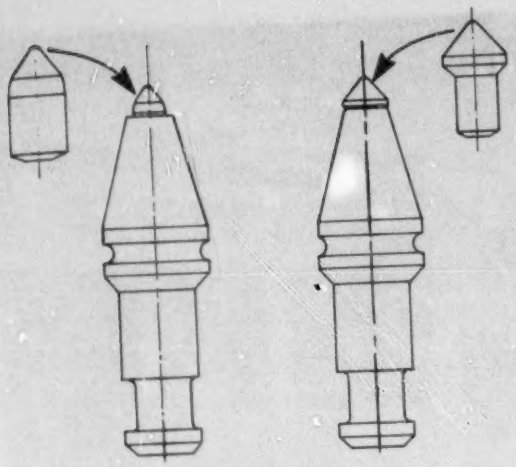
Fire and Explosion Prevention

Anti-Incendive Coal Cutting Bits

L. Cheng, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Conventional mine safety measures aimed at the prevention of frictional face ignitions in underground coal mines are based primarily on adequate ventilation and early detection of hazardous methane accumulations. However, the extraction of deeper, gassier coal seams has led to a significant increase in the frequency of methane ignitions by cutting bits striking rock in mines, which are now averaging about 100 ignitions annually.

Prior Bureau studies on the relative incendivity of various materials used in the construction of coal cutting bits indicated that the steel used in the construction of bit shanks is significantly more incendive than the tungsten carbide cutting tip, and that the tendency for ignition to occur increased greatly with bit wear and shank exposure. This has suggested that the cutting bit geometry can be modified to provide extra protection against early exposure of the shank during the cutting cycle. The "mushroom" bit developed by the Bureau was designed to do this.



When the tips of coal cutting bits become worn, the steel bit shank is exposed resulting in increased potential for methane ignition due to friction. A Bureau-developed anti-incendive mushroom tip (right) provides more shank protection for conical shank cutter bits than a conventional tip (left).

In laboratory tests with full-scale cutting machinery, the mushroom bit design proved significantly better than the conventional bit design in terms of shank protection. This result was confirmed by in-mine tests to compare bit wear rates. In a series of runs which involved cutting approximately 1,000 tons of coal, 69 pct of the recovered mushroom bits showed no apparent wear, whereas only 15 pct of the standard bits were recovered in the unworn state. It is believed that the superior wear characteristics of the mushroom bit will result in a reduction in frictional face ignitions. Additional tests are planned to quantify the anti-incendive character of the new bit design and to further improve these characteristics.

Machine-Mounted Water Sprays for Preventing Frictional Ignition at the Mine Face

W. G. Courtney, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

In response to reports by the Mine Safety and Health Administration that the frequency of frictional face ignitions of methane in underground coal mines was increasing alarmingly, in 1980 the Bureau of Mines undertook a study of the factors governing such ignitions and their control. Initial laboratory studies showed that frictional ignition of a methane-air mixture could be prevented if a simple conventional water spray (0.5 gpm (gallons per minute), 100 psig (pounds per square inch, gage)) impacted the long luminous hot streak that generally formed immediately behind the bit when cutting into sandstone. Subsequent experiments showed that a water spray mounted in front of the cutter bit or impacting the bit, or a poorly oriented back spray was of no benefit in reducing frictional ignition. Thus, the water spray must be carefully oriented to be beneficial in reducing frictional ignition and not merely be splashed in the general vicinity of the bit. Even a correctly oriented back spray did permit frictional ignition when the water pressure was reduced to 40 psig from the usual 100 psig.

To further study and refine the control process, a field shearer drum was fully laced wth 41 chisel-type cutter bits, each bit having its own carefully oriented back spray. The modified shearer drum was sumped into a laboratory block of artificial coal containing a slab of sandstone. With dry cutting, frictional ignition occurred within 5 to 20 sec, but with water sprays operating no ignition was obtained in over 100 sec of cutting. The modified shearer drum is currently undergoing durability tests in an operating coal mine.

Protection of Conveyor Belt Haulageways Against Dust Explosions

L. Cheng, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Rock dust is currently the primary means of defense against coal dust explosions. However, it is well known that conveyor belt haulageways are the most difficult to rock dust adequately. In underground coal mines in foreign countries, passive water barriers are being used for extra protection against coal dust explosions, especially along conveyor belt roadways. Passive barriers are typically made up of numerous water-filled containers mounted near the mine roof. During a coal dust explosion, the dynamic wind forces ahead of the propagating flame can tip or fragment the containers, releasing and dispersing the water to suppress the oncoming flame. Guidelines as to quantity and spacing of these barriers have been developed by the Bureau, based on many explosion suppression tests conducted in the Bruceton (Pa.) Experimental Mine.

The first installation of a passive barrier system in an operating U.S. coal mine was accomplished in

Passive water barriers have been installed in a combined conveyor belt and track haulageway of an underground coal mine to evaluate barrier durability and effect on mining operations.

December 1981, at the Rochester and Pittsburgh Coal Co., Indiana Pa., which is cooperating in a trial to determine the durability of the barriers in U.S. conveyor belt haulageways. Fifty barriers were installed separately in three belt haulageways—25 are a German design and 25 are a modified version developed by the Bureau that is more effective against weak (slow moving) explosions. Information is being obtained on the ability of the barrier system to withstand the mine environment, and on the effect of the system on conveyor belt operation, ventilation, personnel travel, rock dusting, and float coal deposition. To date, there has been no indication that the presence of the barriers interferes with mining operations.

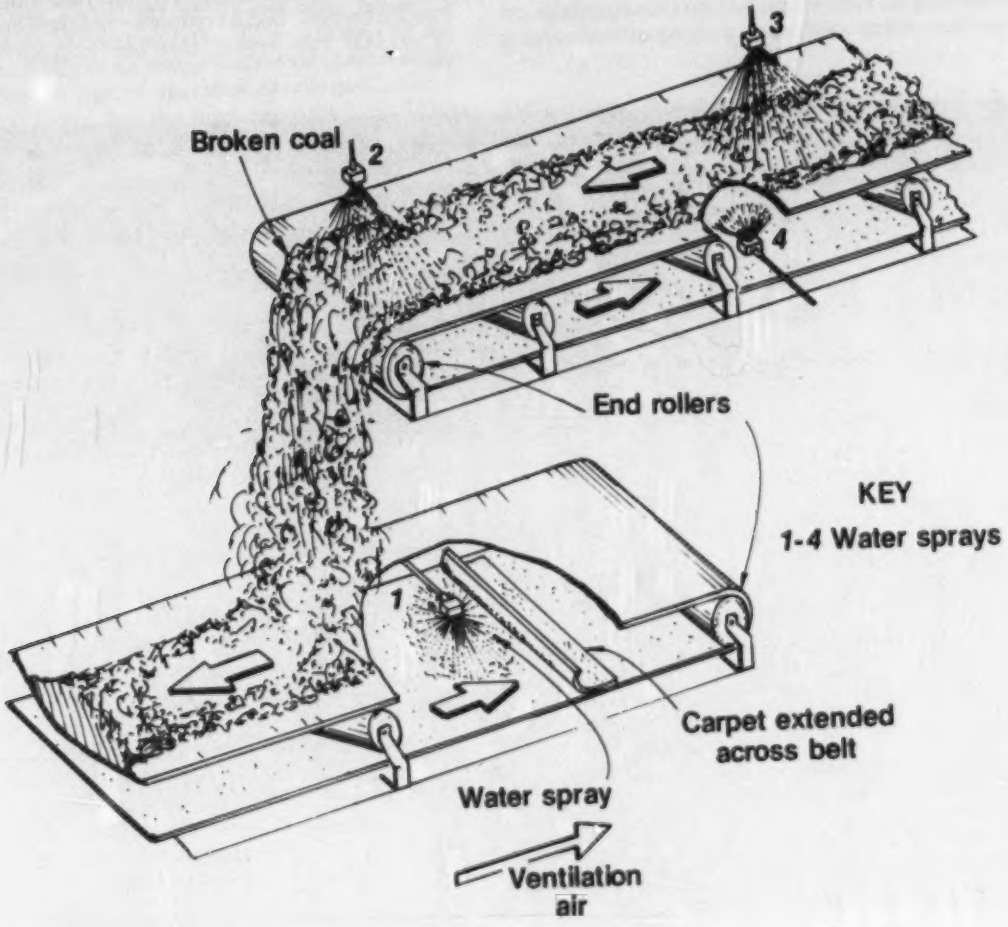
Dust Suppression at Belt Conveyor Transfer Points to Reduce Dust Explosion and Health Hazards

W. G. Courtney, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

The coal dust that inevitably is formed at a belt-to-belt transfer point in a coal mine can be entrained by the airstream and cause a safety and/or health hazard. In practice, the benefit of a water spray at a transfer point will depend upon the degree of dampness of the broken coal being conveyed by the belt and of the belt itself, and probably will vary with the spray's location. Past field reports have indicated a 25-75 pct reduction of airborne respirable dust by a water spray system

at the transfer point, but the effectiveness of the spray in reducing total airborne dust were not documented. To provide such information, the Bureau undertook a study of the effectiveness of water spray location and waterflow rate at a field belt transfer point in reducing airborne respirable and total dust.

Initially, a massive dust buildup between the incoming and outgoing sections of the bottom belt was cleaned out, so that the only significant source of airborne dust was a film of dust adhering to the dry nonload-bearing side of the bottom belt which was dislodged as the belt passed over its end roller at the transfer point. Although this film was very thin (0.0001 lb/ft² (pounds per square foot)) it discharged about 5 g/min (grams per minute) of respirable dust and about 100 g/min of total dust into the airstream. That such a thin dust film should be a severe dust source can be attributed to the fact that about 2,000 square feet per minute of belt surface were passing over the end roller. Best results were obtained with a spray (No. 1) operated in conjunction with a carpet extended across the nonload-bearing side of the bottom belt which insured uniform moistening of the bottom belt and reduced water channeling. With this arrangement, operating at only ⅓ gpm (gallon per minute) of water, the reduction of respirable and total airborne dust was greater than 90 pct, compared with dry operation or the use of the spray (No. 2) at the



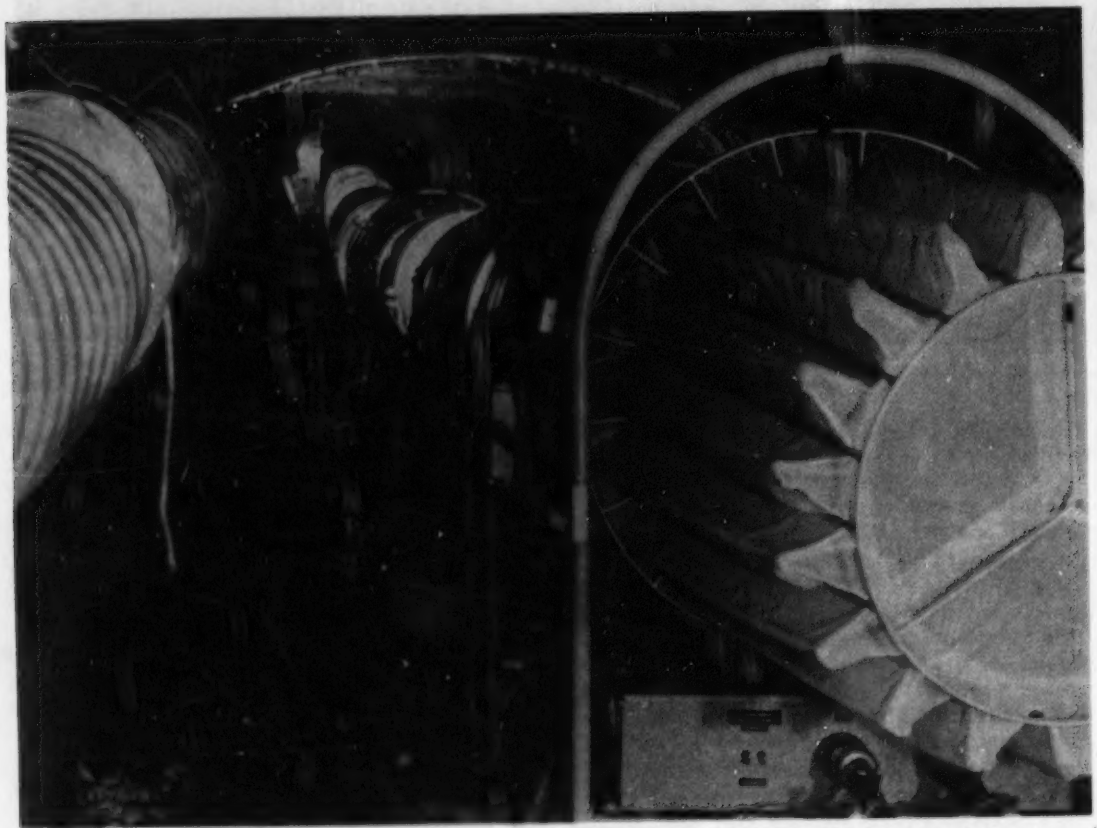
An experimental system was used to study dust control at belt transfer points.

upper belt transfer point operated at 2 gpm. With 1.5 gpm at spray No. 1, respirable dust was similarly reduced, but total airborne dust increased. Without the carpet, both respirable and total dust increased, even with 2 gpm of water. Sprays No. 2 and No. 3 (both above the upper belt) were ineffective. Spray No. 4 (directed to the underside of the upper belt) was slightly more effective but led to severe belt slippage. The No. 1 spray operated at ⅓ gpm with the carpet also greatly reduced dislodgment of total dust at the end roller. Rock dusting at the transfer point could be reduced from about every hour (as required with only the No. 2 spray or when operated dry), to about every 60 hr. As a result of the simple, inexpensive, low-maintenance ⅓-gpm water spray and carpet, the beltway now can perhaps be used as an air intake to the face area; water puddling at the transfer point has been eliminated, rock dusting of the transfer point is much less frequent, and belt wear also should be reduced.

Application of an Inerting Technique To Combat Deep Mine Fires

A. L. Furno, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Extinguishing underground coal mine fires in a potentially explosive atmosphere is difficult and hazardous. A novel approach for controlling mine fires, developed by the Polish mining industry, was investigated by the Bureau in the Bruceton (Pa.) Experimental Mine. The procedure is based on the use of an inert gas generator, that utilizes a modified jet aircraft engine and afterburner to generate combustion products with very low (less than 2 pct) oxygen content, and a volumetric flow rate in excess of 60,000 cfm (cubic feet per minute). Water



An inert gas generator installed in the Bureau's Bruceton (Pa.) Experimental Mine was successfully demonstrated as a means of extinguishing fires in deep U.S. coal mines.

injected into the combustion products provides evaporative cooling and forms a mist with a high cooling capability. At least six major mine fires in Poland and four in Czechoslovakia have been extinguished by this method since 1977.

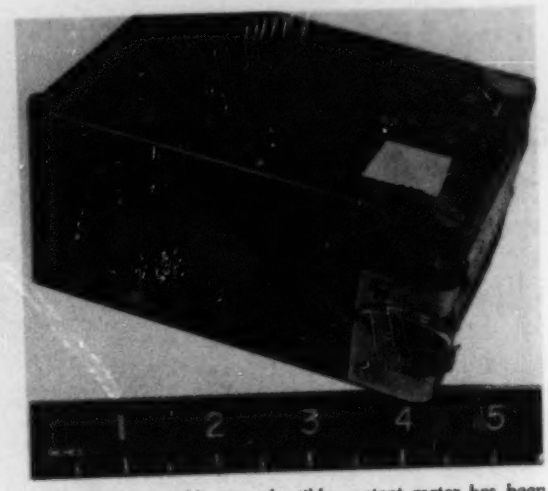
At the Bruceton Experimental Mine, 15 tons of Pittsburgh seam coal were placed in the fire zone of the mine and the inert gas generator was positioned about 100 ft. inside the portal, approximately 1,100 ft. from the fire zone. Five inerting or extinguishment tests were made. The delay (burn time) from start of coal burning to startup of the generator was varied from 2 to 22 hr. The ventilation flow pattern was adjusted so that the output of the generator either passed entirely through the fire zone, or split with an adjoining entry. The oxygen concentration monitored at the coal pile typically was about 4 pct at 10 min and 2 pct at 20 min after generator startup. In all inerting tests, TV monitoring of the burning coal pile indicated flame extinguishment in less than 10 min of operation of the generator. It was concluded that the inert gas system could be successfully applied to mine fires in U.S. coal mines.

Portable Coal Mine Dust Incombustible Meter

H. W. Lang, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

To minimize the possibility of coal dust explosions, Federal regulations require a minimum incombustible content of 65 pct in dust in working areas of underground coal mines and 80 pct in return airways. To verify compliance with these regulations, mine inspectors collect dust samples that are sent to a central laboratory for analysis. Several days elapse before results are obtained. Meanwhile, hazardous dust concentrations could persist undetected at the mine.

As a possible solution to this problem, the Bureau has developed several prototype portable meters that can measure the incombustible content of mine dust directly at the sampling site. The direct measurement principle is the same for all versions. A radioactive source emits gamma radiation that is backscattered by the dust sample; a detector measures the backscattered radiation. Because calcium and magnesium, which are major elements in all rock dust materials, have much higher gamma ray absorption than other elements in coal dust, the higher the incombustible content the less backscattered radiation reaches the detector. A lead shutter, which is pulled aside to take measurements, absorbs the radiation when the unit is not being



A prototype portable incombustible content meter has been developed for rapid analysis of coal dust-rock dust mixtures.

used. Meter calibration is relatively simple, but for accurate results it is essential to use the rock dust material employed by the particular mine being inspected for calibration, before measuring dust samples. Each determination requires about 30 sec for data collection, followed by a 10-sec digital readout display. Indicator lights show when data are being collected, and warning lights are activated for rock dust concentrations below 65 pct and when batteries are low.

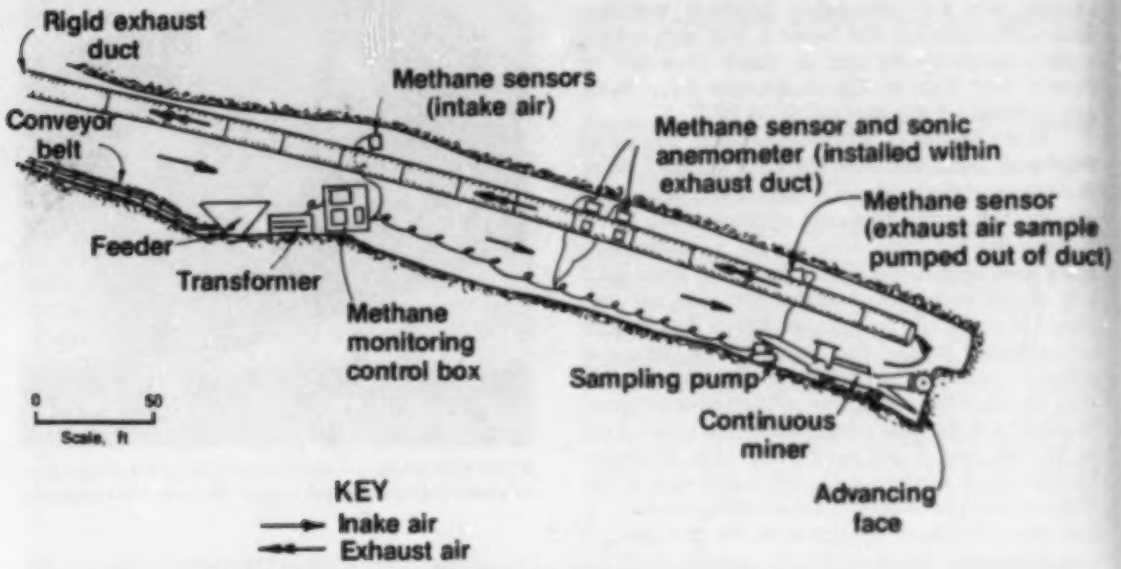
Laboratory tests with one version using known concentration dust samples, showed good correlation between meter readings and analyzed values. In subsequent testing, several different incombustible meters will be compared, using both prepared samples and actual mine dust samples. The best unit will then be upgraded for a complete field evaluation.

Methane Control

Methane Emissions From an Advancing Face in a Domal Salt Mine

A. T. Iannachione, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

At a domal salt mine in Louisiana, much needed information on gas emissions in nonmetal mines is being acquired thanks to a unique opportunity to monitor emissions from an exhaust tubing in a single-entry advancing decline. Over a 5-month period, emission rates were monitored on a face being advanced through different grades of



Installation used to monitor methane emissions at a domal salt mine.

salt by a continuous miner. Intake air traveled down the decline to ventilate the face and was then exhausted through a 30-inch-diameter rigid duct that carried it to the return air away from the face. Methane concentrations and air velocity were measured with methane sensors and a sonic anemometer installed along the duct.

The study showed that—

1. Measurable methane emissions (15 to 56 ft^3/ton (cubic feet per ton)) do occur from a low-grade salt during production; emission is far less (<15 ft^3/ton) for high grade salt.

2. Methane emissions decrease with time after a production shift, with methane concentrations in the return air being less than 0.01 pct within several hours after production.

3. Methane emission rates vary considerably during face advancement.

4. Geologic and geochemical characteristics of domal salt influence methane emission rates during production from advancing faces.

Wireless Real-Time Survey Tool

G. L. Finfinger, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Methane drainage through long horizontal holes drilled into the coal face has proven effective in reducing methane emissions in coal mine workings. However, it is essential for the borehole trajectory to be accurately controlled so that it remains within the coal seam during drilling. To achieve maximum trajectory control, the horizontal hole must be surveyed to determine bit location every 20 ft. during drilling. Currently, surveying is done by permissible photographic systems that are placed in the drill pipe and pumped with water to the end of the hole. After a preset time, the survey tool is extracted from inside the drill pipe by means of a wireline. For holes drilled to 1,000 ft., the average time required for a survey by this is about 16 min; it increases to 34 min for hole depths of 2,000 ft. As a result, over 50 pct of the time available for drilling is now spent in surveying.

The Bureau has developed a wireless electronic surveying system that can be located behind the bit where it measures bit inclination, bit azimuth, and bit roll. The measurements are telemetered over the drill pipe and displayed in less than 2 min on a driller's console, thus eliminating the need to withdraw the surveying tool to take a reading. Use of the electronic system will reduce surveying time at least 40 pct, will aid in maintaining more precise hole direction, and will permit routine drilling to depths of more than 2,000 ft. This development received an IR-100 award in 1982.

Borehole trajectory readings are taken with a wireless real-time survey tool which reduces surveying time by 40 pct.

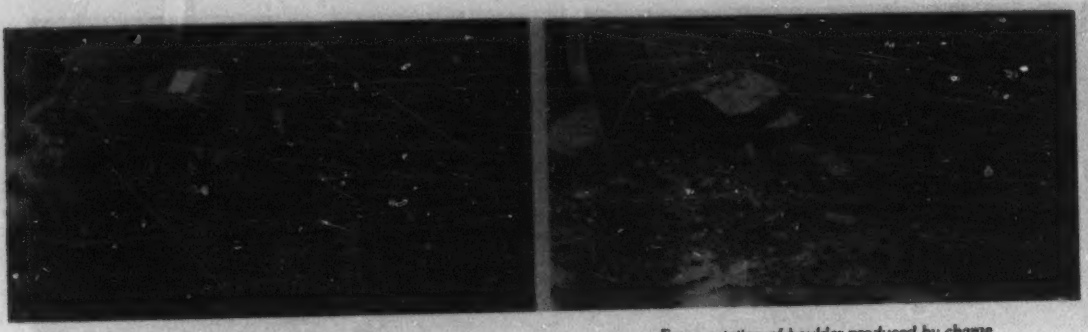
Explosives

Sheathed Permissible Explosive Charge for Unconfined Shooting

R. J. Mainiero, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Open or unconfined blasting—an explosive charge is fired on a rock surface instead of in a drilled hole—is currently prohibited in underground coal mines even with a permissible explosive because of the danger of igniting flammable methane gas and coal dust which could result in a massive, mine-wide explosion. If the danger of such an ignition were eliminated, unconfined blasting could be useful in reducing certain other hazards. Loose mine roof that is difficult to pry down thereby exposing miners to the danger of falling rock slabs could be rendered harmless with unconfined blasts. Open shooting could also be used for safely removing overhanging strata, quickly leveling piles of fallen roof rock, and breaking large boulders.

To eliminate this ignition hazard, the Bureau began development of a new type of nonincendive explosive charge that could be safely fired unconfined in gassy or dusty mine atmosphere. The initial versions utilized metal-lined conical shaped charges that were rigidly packaged. This resulted in a tall charge, not well adapted to shooting in crevices, with the explosive energy too concentrated in the region under the cone, and not adaptable to rough rock surfaces. A new pancake-shaped version of the charge has been developed. As in the previous version, 1.5 lb of aluminized permissible water gel is completely surrounded by a 0.5-in layer of damp salt. However, a covering of cloth-reinforced latex rubber gives the charge sufficient flexibility to conform to rough rock surfaces. This new charge is only 2 in thick, 7 in in diameter, and can be inserted into crevices. This version has been extensively tested in both 9 pct methane-air and in predispersed coal dust-methane-air atmospheres. It has never produced an ignition. Its rock-breaking effectiveness and other uses have been demonstrated in numerous field trials. A single charge can break boulders weighing 1 to 2 tons. Up to five charges have been used to break very large slabs of rock weighing over 10 tons. The effectiveness of the



Boulder with explosive charge in place. *Fragmentation of boulder produced by charge.*

A limestone boulder was broken by a prototype sheathed permissible explosive charge. The boulder measured 44 by 22 by 19 in and had an estimated weight of 1,800 lb.

charge for conveniently and safely shooting down partly separated roof slabs and for blasting away roof support cribs has also been established.

Safety Procedures for Guarding Blast Affected Areas

Dennis V. D'Andrea, Technical Project Officer
Twin Cities Research Center, Minneapolis, Minn.

Failure of the blast area security system is the most frequent cause of mine blasting accidents. Blast area security problems are failure to clear the blast zone, failure of personnel to follow instructions, inadequate guarding, and failure to retreat to a safe location or take adequate cover. The Bureau examined the state of the art of blast area guarding practices and made recommendations for procedures and new technology that would improve safety.

Examples of blast area guarding practices that were considered to represent the best systems currently in use were prepared for two surface and three underground mines. The mines selected as good examples were well above average when compared with the industry as a whole. Other mines would benefit by adopting some of the blast security practices described. It was concluded that blast area security suffers more from poor procedures than from a lack of advanced technology and that many accidents could be prevented by improving minesite blast security practices.

The basic elements of an effective blast area security system include commitment to safety, training, definition of blasting authority, planning, defining blast zone boundaries, placement of guards, clearing procedure, personnel accounting, warning signals, and blasting crew communications. These elements are considered guidelines since the actual security requirements will vary considerably from minesite to minesite.

Surveillance and detection technology used in other industrial applications has some potential for use in guarding blast areas but the cost of most exotic electronic systems would be prohibitive. Single entry intrusion detectors systems, such as infrared, could be developed for underground mines. Perimeter detectors have some potential for surface mines. Technology also exists for computerized tracking of personnel which would eliminate uncertainty of miner location at blast time.

Test Development and Verification in Support of Department of Transportation and United Nations Classification of Explosives

J. E. Hay, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

For several years, the Group of Experts on Explosives of the United Nations Committee of Experts on the Transport of Dangerous Goods has been engaged in developing a procedure for determining if a substance or article possesses explosive properties and, if so, the degree and character of the explosion hazard. This effort has culminated in the publication of a list of specific tests for predicting hazard levels of explosive substances and a classification flow chart.

The object is to establish test procedures and criteria for classifying explosive substances so that explosive properties are assigned to substances known to present explosion hazards, but not to substances with a long history of transportation without any explosion-related problems. Among the tests are the gap test, the cap test, the

deflagration-to-detonation transition (DDT) test, and the cavitated gap test, all developed by the Bureau. Several countries are in the process of officially adopting the classification scheme for internally regulating the transport of dangerous goods.

Bureau research, in support of the choice of the DDT test, has shown that the specific material used to ignite the sample in the test does not have a strong influence on the outcome; ignitions of different compositions but similar thermal output give essentially similar results as determined by the degree of fragmentation of the test vessel. This is important in an international standard test, since identical materials may not be available in all participating countries. Classification criteria have also been developed based on two tests that are critical in establishing the upper limit of sensitivity (above which a substance should not be transported in bulk)—the drop-weight impact sensitivity test and a friction sensitivity test.

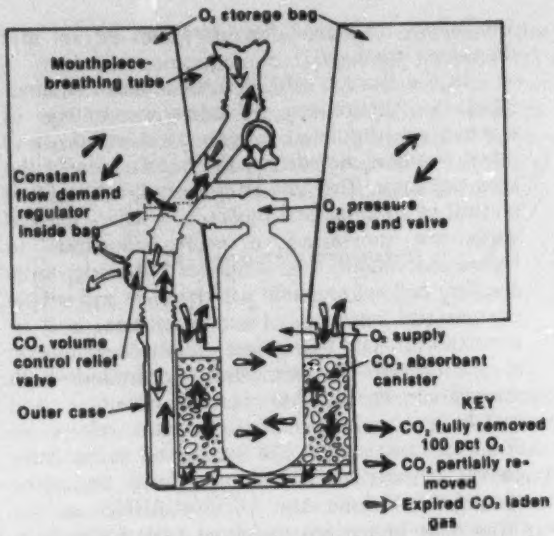


Diagram showing operation of a self-contained compressed oxygen breathing apparatus (SCEBA 60).

Postdisaster and Rescue Survival

Compressed Oxygen Self-Rescuer

N. Kyriazi, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Federal regulations require that all underground coal miners have access to oxygen self-rescuers for escape in case of a disaster that makes the mine atmosphere toxic and/or oxygen deficient. Self-rescuers in which oxygen is generated by a chemical reaction have been available for a number of years. However, recent advances of high-pressure-bottle technology have prompted research into compressed oxygen self-rescuers that could offer size and weight advantages over existing chemical self-rescuers. A Bureau project has resulted in the development of a 60-min, self-contained compressed oxygen breathing apparatus, known as the SCEBA 60. It weighs 2.95 kg (kilograms) as compared to 3.8 kg of the lightest chemical-oxygen (KO_2) self-rescuer, and 3.4 kg for the lightest compressed oxygen self-rescuer presently available. The SCEBA 60 is as small as the smallest available oxygen self-rescuer of either type (5.8 liters).

In addition to the normal breathing apparatus components (mouthbit and noseplug, breathing hose, carbon dioxide absorbant canister, oxygen bottle, and breathing bag), the SCEBA 60 has certain novel features, such as a lightweight, fiberglass-wrapped oxygen bottle positioned so that it is surrounded by the CO_2 scrubber, which conserves space and absorbs heat from the scrubber. Also unique are a temperature-compensating pressure indicator, and a relief valve that is triggered by bag volume but which dumps air in the breathing hose that has not yet been scrubbed of CO_2, thus sparing the CO_2 scrubber to some degree. Although initially designed for coal mines, the SCEBA 60 is suitable for use in any workplace plagued by inundation of irrespirable gases. The apparatus is awaiting approval and certification by the National Institute for Occupational Safety and Health (NIOSH), after which it will be commercially available.

Automated Breathing Metabolic Simulator

N. Kyriazi, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Breathing apparatus developed for use in the mining industry undergoes extensive testing prior to certification by the National Institute of Occupational Safety and Health (NIOSH). Conventionally, this testing has been done on human subjects with obvious disadvantages due to unavoidable human factors. The automated breathing metabolic simulator (ABMS) developed by the Bureau represents a significant advance in standardizing test procedures and results. The metabolic demand on the breathing apparatus is repeatable and quantifiable. Oxygen consumption, carbon dioxide production,

ventilation, and peak flow rate can be set and measured precisely.

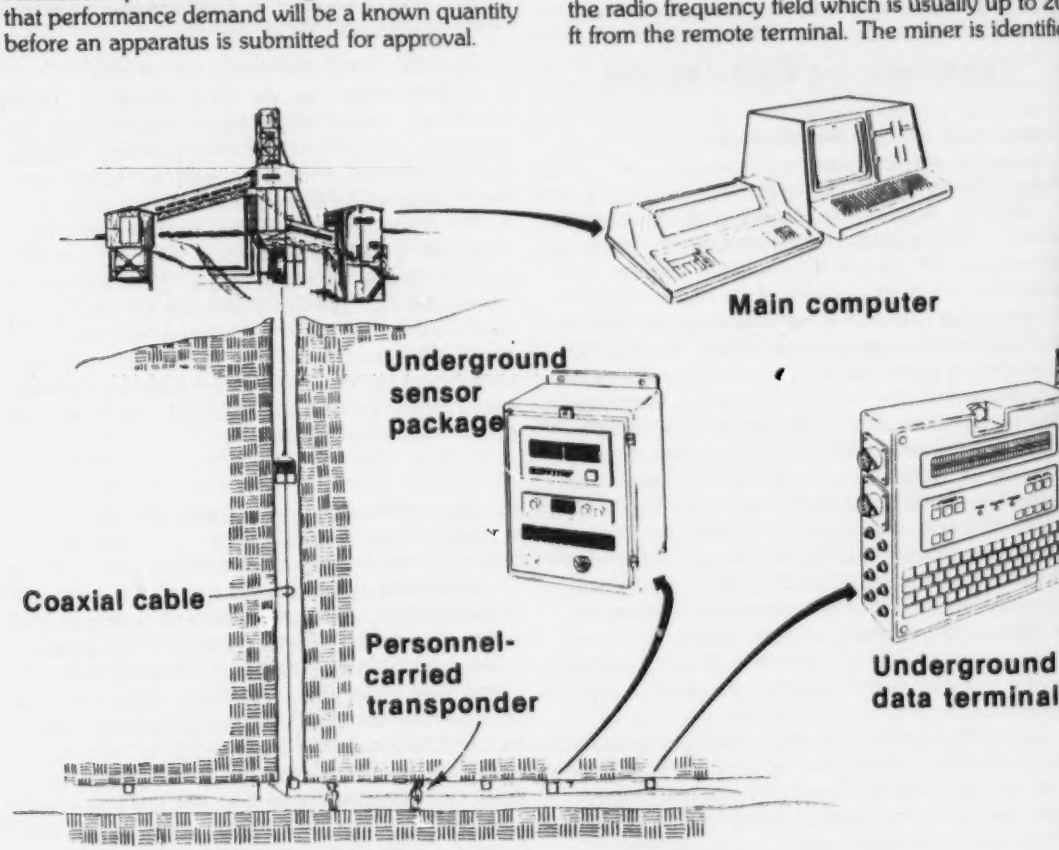
In the Bureau's ABMS, metabolism is simulated by withdrawing a certain percentage of inspired air (simulated oxygen consumption) and adding carbon dioxide on the exhale side of the lung simulator. The flow path is unidirectional and consisit of an inhalation mixing box where inhaled gases are monitored, a main bellowfram (a bellow-diaphragm) that simulates breathing, three ancillary bellowframs that withdraw air and supply oxygen and nitrogen, a humidifier box, and an exhalation mixing box where metabolic simulation is monitored. A computer controlled ball-screwdriver is used to control breathing and metabolic simulation. The computer allows an entire human subject test simulation to be completely automated. NIOSH standards are being revised to include use of the ABMS in the certification procedure, making it more equitable in that performance demand will be a known quantity before an apparatus is submitted for approval.

Mine Personnel Locator and In-Mine Activity Controller

James R. McVey, Principal Investigator
Spokane Research Center, Spokane, Wash.

The inability to quickly determine the locatio of personnel and control critical undergroun activities generally hampers rescue operation during a mine disaster. This fact and the need fo overall mine monitoring to improve safety an minerals production have brought about th conceptual design of a mine personnel locator an in-mine activity controller.

The systen will automatically log the miner equipment into the mine and keep track of th direction of travel and location underground. Th system, which has been designed but not bui consists of a host computer, strategically locate remote terminals, and cap-lamp transponde (transceivers). Each miner or piece of equipment automatically interrogated while passing or enteri the radio frequency field which is usually up to 2 ft from the remote terminal. The miner is identifi



Conceptual view of a mine personnel locator and in-mine activity controller.

by an assigned code transmitted from the cap-lamp battery transponder to the remote terminal. The remote terminal retransmits this signal to the surface, updating the miner location and direction of travel in the next polling from the host computer (continuous polling). Equipment is polled in a similar manner.

The system is also designed as a total mine-wide monitoring system. The remote terminal not only monitors personnel and equipment locations but is also equipped with analog and digital outputs for measurement and control. These input-output functions allow measurement of various parameters and activities such as ventilation, toxic gases, smoke or fire detection, and a host of others.

An alpha-numeric display and keyboard allow sending and receiving of messages between terminals and the host computer. Paging is also provided. A visual page is displayed at the underground terminal and, at the same time, a page indicator light illuminates on the miner's cap-lamp battery if he or she is within the terminal's transmitting range.

The mine personnel locator, consists of the main host computer and data printer, interconnecting communications data link (coaxial or fiber optic), remote terminals, and cap-lamp transponders. The host computer and printer are commercially available. The underground terminal and transponder have been designed but not built.

Systems Engineering

Research Results at Lake Lynn Laboratory

M. J. Sapko, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

On-stream explosion testing has commenced at the Bureau's Lake Lynn Laboratory, in Fayette County, Pa., about 60 miles southeast of Pittsburgh. This composite mine-scale facility which has four drifts, 18 ft wide and 7 ft high, driven 1,600 ft long and interconnected with a 500-ft longwall face, simulates modern mining entry parameters with its wider openings made possible by advanced roof support technology. Among the

Artist conception of the Bureau of Mines Lake Lynn Laboratory showing various mine configurations available for mine-scale research.

facility's unique features is the possibility to experiment with an array of underground mining section configurations such as single entry, triple entry with crosscuts, and a longwall panel. All of these configurations are obtainable by opening or closing two 67-ton explosionproof movable bulkheads. Extensive instrumentation utilizes the latest data acquisition and processing technology to provide accurate and immediate measurements of test parameters. The Laboratory will allow testing of passive and active barriers for the suppression of weak through strong explosions and the evaluation of ignition detection and suppression systems around actual longwall and continuous mining machines.

On March 4, 1982, gas explosion scaling experiments were initiated in the single entry to gather baseline information for extrapolation of Bruceton (Pa.) Experimental Coal Mine data to the more realistic Lake Lynn entries. The initial hypothesis was that gas explosions could be scaled by a simple length-to-width relationship. However, preliminary results indicate that gas explosion characteristics are different for the two facilities and that simple scaling relationships are not appropriate.

The surface facilities at Lake Lynn are being used for large-scale open fire experiments since environmental constraints prohibit them at Bruceton. Recent research has included fire equivalency testing of plastic and metal containers. The plastic containers, which had passed certain small-scale fire tests, melted rapidly when exposed to a large fire, releasing combustible fluid that increased the fire intensity. Full-scale flammability tests of ventilation ducting are providing information needed to develop a small-scale test method for flexible and rigid ventilation ducting.

Lake Lynn also features an incendivity gallery where explosives and blasting agents can be tested in various flammable atmospheres under more realistic conditions than at Bruceton. The nonincendivity and rockbreaking performance of a new sheathed explosive charge was established here.

Statistical Mine Accident Analysis

John C. Kerkering, Principal Investigator
Spokane Research Center, Spokane, Wash.

The Mine Safety and Health Administration (MSHA) has been collecting data on mine accidents for over 10 years. Because there are approximately 40,000 accidents reported each year, the data are coded and stored on a computer for quick and accurate retrieval. Until recently, it has been difficult to use the data for purposes other than statistical summaries of mining accident types. Using the data to make statistical inferences about mining accidents has been difficult because an appropriate analysis technique was lacking and the data were not collected for this purpose.

The Bureau is developing a valid statistical inference technique that goes beyond simple summary statistics. The most promising technique to date is management oversight and risk tree analysis (MORT). Part of this method involves using historical accident data (the number of accidents and their severity) to calculate the expected loss (risk) for a given mining activity. The availability of large high-speed computers allows this information to be quickly calculated from the large mass of mining accident data. The risk measures can be used to rank mining activities according to hazard. Mine safety research can be planned so as to establish acceptable levels of risk. Risk can also be translated into dollars for cost-benefit analysis studies.

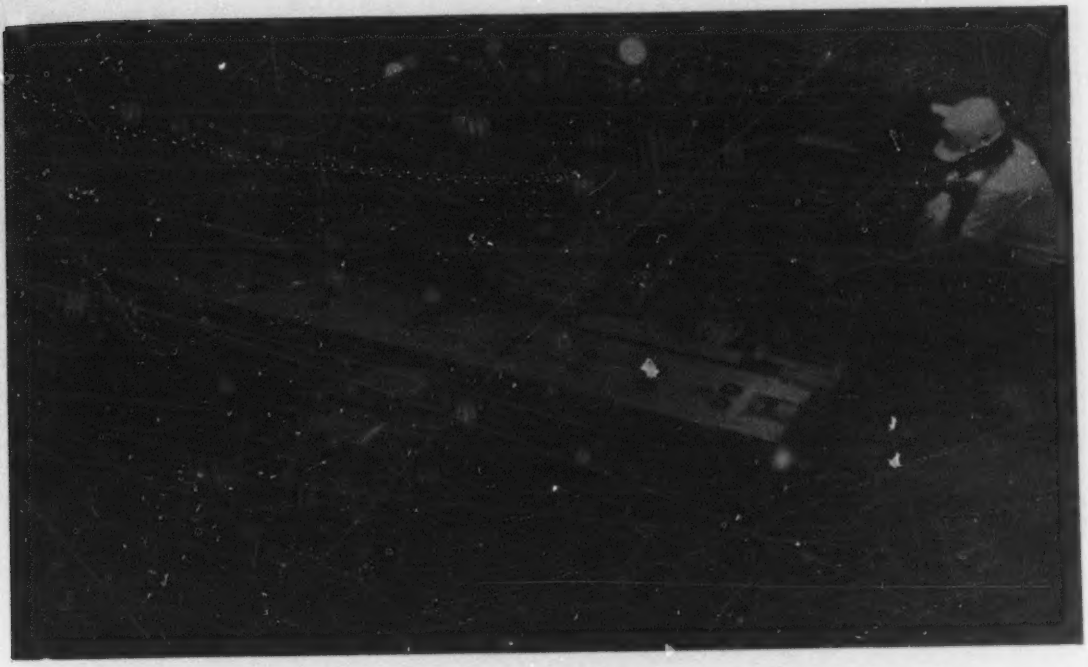
MORT can also be used to calculate the maximum risk for a given mining activity and probable reoccurrences of any size accident, using extreme value analysis. It will also identify accident trends, unique causes of accidents, and weaknesses in management. Knowledge of management deficiencies would aid in preparing a mine safety program and predicting the results of the program.

Ground Control

Surface Evaluation of the 4M Miniminer System

A. J. Kwitowski, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

A new mining system designed specifically for low coal and known as the 4M miniminer system was tested in the Department of Energy's Mining Equipment Test Facility at Bruceton, Pa. The miniminer system, which consists of a continuous miner, a bridge carrier, bridge conveyor, a panline and crossover dump, was found to be very well suited to low capacity, thin seam coal mining. It is very maneuverable, capable of cutting true 90° crosscuts, and is compatible with a wide range of roof support hardware. From the Bureau tests it appeared to be equal or superior to other existing mining equipment with respect to dust and noise generation. On the negative side, surface testing showed that the miniminer cut and conveyed coal



A new mining system (4M miniminer) designed for use on low-coal faces has undergone surface testing.

at rates below the manufacturer's specifications; was apparently underpowered in the gathering and conveying functions; had several unreliable components; and could create a hazard for the bridge carrier operator under certain conditions. Based on the results of this surface evaluation, the miniminer will be modified by the manufacturer, and the modified system will be evaluated in an underground mine. These results will be used to verify surface test procedures.

Automated Temporary Roof Support for Single, Fixed-Head Roof Drills—An Update

C. J. Chislaghi, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Setting of mechanical jacks or wood posts under unsupported roof accounts for about 20 pct of roof fall fatalities in coal mines. The Bureau developed a prototype version of a remotely operated, automated, temporary roof support (ATRS) for use on single, fixed-head roof drilling machines (squirmers) that operate in low coal seams (less than 42 in thick). This ATRS was designed to eliminate the need for miners to go under unsupported roof to set or remove temporary support prior to or during the roof bolting cycle. Extensive field tests were conducted with the ATRS at Imperial Colliery Co.'s No. 20 Mine, near Beckley, W. Va. In the course of these trials, the original aluminum components were replaced by steel which makes the squirmer more stable when tramming and it is easier to weld underground. In its present version, the ATRS has a 10-ft-long, steel, wide-flange beam supported by two double-acting, telescoping hydraulic cylinders. A steel sleeve in the center of the beam fits on top of the squirmer drill head. The ATRS is carried from place to place on the squirmer drill head, but during bolting it is connected to the squirmer by only two hydraulic lines. To use the ATRS, the squirmer operator sets it firmly against the unsupported mine roof while remaining under permanently supported roof, then lowers the drill head away from the ATRS, and drills and bolts a row of permanent supports. The squirmer operator then reconnects the drill head to the ATRS, retracts it from the roof, advances inby, and repeats the sequence until the work place is bolted up to the face.

The Bureau's ATRS meets general design requirements of the Mine Health and Safety Administration (MSHA); both hydraulic cylinders

An automated, temporary roof support mounted on low-coal roof drilling machines eliminates the need for miners to go under unsupported roof to set or remove temporary support before or during the roof bolting cycle.

supporting the ATRS have check valves to prevent sudden collapse in the event of a ruptured hydraulic line or broken fitting; the ATRS hydraulic circuit contains an accumulator charged by the squirmer hydraulic system pressure which keeps the ATRS firmly set against the mine roof even if roof rock is pulled up during the bolting cycle. As a result of the successful field test, an amended roof control plan, which requires the use of the Bureau's ATRS during roof bolting, was submitted by the company and approved by MSHA.

Remote-Controlled Bolter for Metal-Nonmetal Mines

Robert R. Thompson, Technical Project Officer
Spokane Research Center, Spokane, Wash.

Rock bolting in metal-nonmetal mines differs from roof bolting in coal mines in two ways—rock drillability and opening size. In most coal mines, the top is soft and can be drilled with rotary drills. In contrast, the majority of drilling in metal-nonmetal mines is done with rotary percussion drills.

Bolting is a hazardous occupation, resulting in a large number of fatal and nonfatal mine accidents each year. The Bureau of Mines and industry have devoted considerable effort in developing automated roof-bolting systems for coal mines. However, most coal-mine roof bolters are not designed for mining heights greater than 10 ft. This technology is being expanded in developing a remote-controlled bolter for metal mines with high backs. The Bureau has designed and built a machine that allows the operator to perform all bolting functions from a protected cab. The machine can operate in mine openings 10 to 26 ft in height and has a carrousel that holds eight bolts of various lengths, if needed. The bolter can install either mechanical bolts, resin bolts, or friction stabilizers (split sets), with minimal changeover time.

Following debugging in the laboratory, the machine is being tested in the Bureau's Lake Lynn (Pa.) Laboratory. The system will be field tested in an operating underground metal or nonmetal mine.

Epoxy Cartridges for Roof Bolts

Robert R. Thompson, Technical Project Officer
Spokane Research Center, Spokane, Wash.

During the last few years, the Bureau has been developing a fiberglass reinforced-epoxy pumpable roof bolt. As a spinoff of this effort, an epoxy cartridge has been developed. The epoxy developed for pumping has been modified by adding more fillers. The cartridges will be usable by the miner on a one-to-one replacement for the polyester cartridges now being used for fully grouted roof bolts at a similar cost. The epoxy

A remote-controlled bolter for metal-nonmetal mines has been developed and is undergoing testing.

cartridges will have the following advantages over the polyester cartridges:

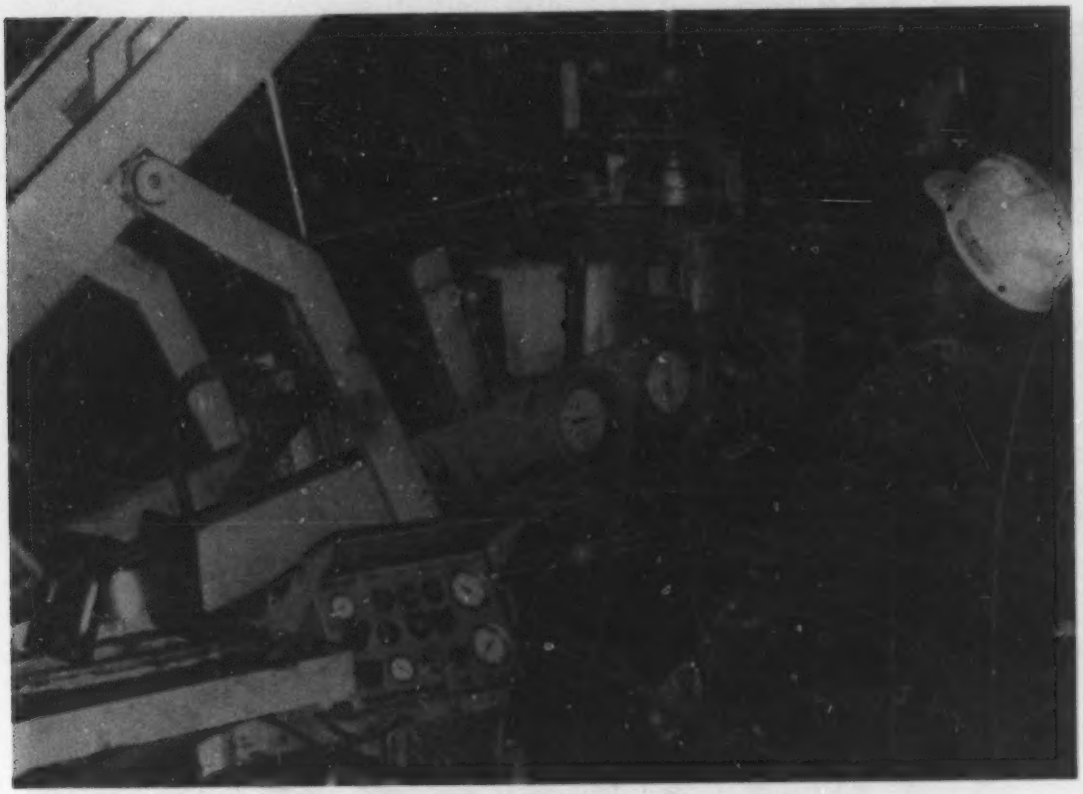
1. A higher bond strength—the epoxy produces a bond to the rock giving bond strengths of over 25,000 lb/ft (pounds per foot).
2. A flashpoint of over 300° F as compared with 100° F with polyester.
3. Longer shelf life.
4. Better stability at low and high temperatures—this will reduce storage and material handling problems.

The Bureau has conducted a standard MSHA two-intersection test in an underground coal mine. Limited pull test data indicate that the epoxy has approximately twice the bond strength per linear foot that the polyester does during the first 5 to 15 min. After 30 min, the epoxy has at least 1.5 times the bond strength per linear foot as the polyester. The total installation time of the epoxy is the same as polyester, but test results indicate that this total placement time may be reduced for the epoxy.

Uniform Roof Bolt Tension

Robert R. Thompson, Technical Project Officer
Spokane Research Center, Spokane, Wash.

Several fundamental questions regarding the amount of tension necessary to maximize the effectiveness of mechanically anchored roof bolts have been repeatedly raised by the Bureau, the Mine Safety and Health Administration, and the coal mining industry. The Bureau has completed several projects relating to uniform tension for roof bolts. In the first project, a device was developed for roof-bolting machines which permitted accurate reading of the torque in roof bolts. Subsequent



Full control of the bolting operation can provide uniform roof bolt tension which may result in better roof control.

research determined that other factors, such as bolthead galling, washer hardness, bolt thread friction, and "bleed off" due to strata characteristics, were critical in achieving uniform roof bolt tension. Studies also indicated that the most important factor in the use of mechanical bolts for mine roof support was the maintenance of uniform roof bolt tension.

In conventional practice, a mechanical bolt installation is characterized by a tension variability coefficient of 45 pct within an hour after installation. This implies that 2.2 pct of the bolts, or one bolt in every other advance bolted, retains less than 10 pct of the nominal installation tension within an hour of installation. Similarly, an estimated 2 pct of the bolts installed have little or no anchorage owing to the nature of the local rock. In effect, one bolt in every advance may be considered removed. The unsupported span in this area is then doubled. If this is done in a conventional beam, stresses in the beam are quadrupled. Eventually one of the ineffective bolts coincides with a local weakness in the roof structure and triggers a fall.

Combining the results of research to date could lead to a bolt installation procedure that would greatly minimize the potential for ineffective roof bolts. A long-term underground field evaluation is in progress to determine—

1. If roof bolts can be installed with uniform tension, despite wide variations in roof conditions.
2. If uniformly tensioned bolts result in better roof control.
3. The relative cost benefit of maintaining uniformly tensioned bolts to obtain good support.

Roof Bolt Bond Tester

Ray Stateham, Technical Project Officer
Denver Research Center, Denver, Colo.

Historically, the greatest single cause of death in coal mines in the United States has been falling

rock. To support the rock and prevent roof falls, several types of roof bolts are used to bolt the rock in place and stabilize the rock mass. One type of these bolts is cemented in place using a resin grout. When properly installed, these bolts are bonded to the rock over their entire surface. They are very effective in supporting mine roof and, because they are, more than 20 million resin-grouted bolts are used in this country each year.

Currently, torque tests are used to evaluate the integrity of resin-grouted bolts after they are installed. This method of testing has been carried over from testing earlier types of bolts. Torque tests are unsatisfactory for testing resin-grouted bolts because torque applied to the bolt can cause it to turn, destroying the bond between the rock and the bolt.

To meet the need for a satisfactory test device, the Bureau has developed a roof bolt bond tester for nondestructive testing of resin-grouted bolts after their installation in rock around mine openings. The tester is lightweight and small in size for portability and easy use. The actual size is approximately the same as a five-cell flashlight. Small nickel-cadmium batteries supply ample power to the unit for a full shift of operation without recharging, though an on-off switch is provided so that the operator can save batteries when the instrument is not in use.

A roof bolt bond tester has been developed for nondestructive testing of the bonding integrity of resin-grouted roof bolts.

Energy transfer between two or more media, the concept on which the tester is based, is well established in other industries. In accordance with this concept, the tester uses a piezoelectric transducer to impart a measured pulse of energy to the bolt and then listens for reflected energy. Where a good bolt-resin-rock bond exists, the energy passes from the bolt through the resin and dissipates into the rock. Where proper bonding does not exist, the energy reflects back through the bolt to the tester. The instrument measures the reflected energy and compares it with the original pulse. The amount of energy reflected back is an indicator of the portion of the bolt surface that is not bonded, and the ratio of the energy in the original pulse to the reflected energy is used in evaluating bond integrity. This cycle of pulsing is repeated at a rate of 200 times per second.

Operation of the instrument is simple. When the off-on switch is turned on, a battery condition indicator lights, either green for a properly charged power supply or red for an improperly charged supply. Also when the switch is first turned on, the instrument automatically initiates a 4-sec self-check procedure to verify proper operation. The operator then selects the proper bolt length range (2½ to 4 ft or 4 to 8 ft) and pushes the instrument firmly over the bolthead. When a coupling force of about 5 lb. is reached the instrument automatically reads the bolts condition, stops the pulse-listen cycle, and displays the readout. The instrument has three possible readings: red, yellow, or green, corresponding to bad (less than 50 pct bonded), marginal (50 to 75 pct bonded), or good (more than 75 pct bonded). The light stays on for 4 sec, then the instrument resets itself for the next test.

Underground tests of the roof bolt bond tester were made in the Bureau's experimental mine at Bruceton, Pa., where 182 bolts were installed with resin columns ranging 25 to 100 pct of the bolt surface. Test results were confirmed by overcoring selected bolts. Tester accuracy was better than 90 pct.

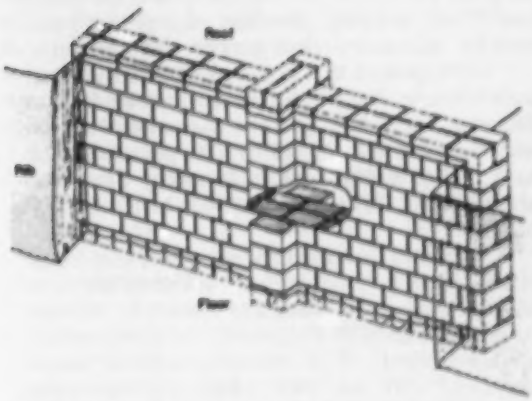
Additional tests are continuing in a wide range of rock types in mines across the United States to evaluate calibration needs and instrument durability and repeatability. It appears that some calibration adjustment will be necessary to allow proper operation with the wide range of rock types encountered. Several improvements are planned to correct minor problems that have been encountered during these extended tests.

Anchorage of Inundation Bulkheads in Coal Mine Openings

G. J. Chekan, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Bulkheads are constructed in coal mine roadways to keep water from flooded abandoned workings or other bodies of water out of the workplace. They are also used as dams to impound waste water in underground reservoirs for treatment. A major problem in the construction of such bulkheads is to provide sufficient anchorage to the mine roof, ribs, and floor. Failure of the anchorage system, or of the bulkhead itself, can result in an inundation that endangers the workers and can mean loss of the mine. As part of an effort to provide better protection against flooding in coal mines, conventional bulkheads and seals are being constructed and hydrostatically tested in the Bureau's Bruceton (Pa.) Safety Research Coal Mine. Anchorage system designs are being modified to strengthen the bulkhead structure and improve its water holding capabilities.

A concrete block bulkhead, commonly used in coal mines for explosion supression, has been tested. The bulkhead was 16 in thick and anchored 16 in into each rib and 12 in into the floor. Solid concrete blocks (16 by 8 by 16 in) with a compressive strength of 1,800 psi (pounds per square inch) were laid in a transverse pattern, with a pilaster center for additional support. The bulkhead withstood 50 psi of hydrostatic pressure before water began to leak through the structure, a sign of impending failure. This hydrostatic pressure is approximately equivalent to the dynamic pressures withstood by similar bulkheads during explosion tests conducted in the Bruceton Experimental Coal Mine. Other bulkheads scheduled for testing include flyash-cement and concrete constructions. Information on the design, construction and test results for each bulkhead, together with pertinent recommendations, will be made available to industry.



A concrete block bulkhead laid in a transverse pattern with a pilaster center was tested as a means to protect against flooding in coal mines.

Synthetic Radar for Coal Mine Hazard Detection

Richard J. Leckenby, Technical Project Officer
Denver Research Center, Denver, Colo.

Ground penetrating radar methods can be used to detect and locate hazardous geologic features in advance of mining. Such a "look-ahead" capability can greatly reduce the risk of inadvertently mining into potential hazards such as abandoned mines, water- or gas-filled voids, well casings, channel sands, faults, and clay veins. Rapid in-seam radar measurements can be taken from the working face in a coal mine with minimal disruption of the normal mining operation, and can provide early warning for preventive planning when a suspected hazard is identified.

Synthetic pulse radar is a microprocessor-based electromagnetic technique being developed by the Bureau for hazard detection in underground coal mines. The system discretely transmits electromagnetic waves of different frequencies between 20 and 160 MHz (megahertz). Echoes from potential hazards are recorded as changes in amplitude and phase of the transmitted continuous waves. After the different frequencies have been transmitted and received, a mathematical algorithm

Breadboard synthetic pulse radar system for detection of potential mining hazards is being tested underground in West Virginia.

is applied to the data to show the hazard as a pulse occurring as a function of time.

The major advantage of the synthetic pulse method over the conventional short pulse method is that deeper penetration using less peak power can be achieved. This allows for the design of a permissible system that can assure adequate warning when a hazard is detected.

The construction of a prototype system, designed to meet permissibility standards for coal mine use, is now nearing completion. It is anticipated that the system will be able to achieve pulse reflections from penetration depths up to 200 ft and transmission as great as 700 ft.

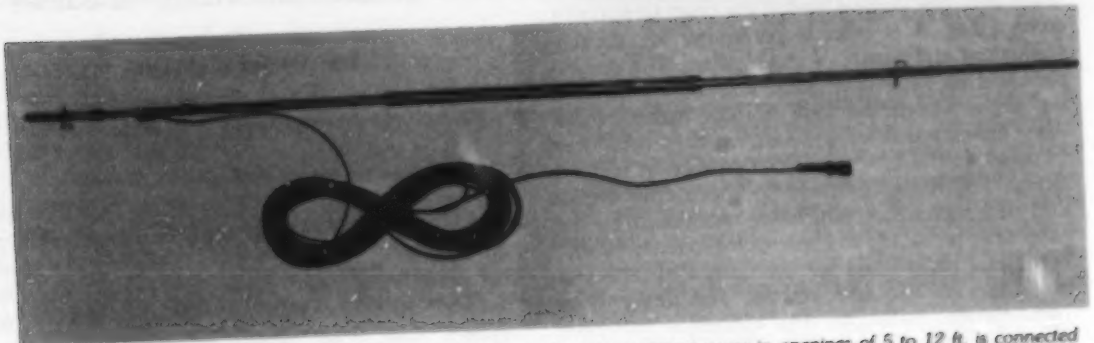
Closure-Rate Instruments for Roof Fall Prediction

James R. McVey, Principal Investigator
Spokane Research Center, Spokane, Wash.

Knowledge of the change in roof-to-floor closure rates during mining operations can help predict an imminent roof fall. Two instruments to measure the closure rate and to produce alarms when a preset critical rate is reached are being developed. One instrument utilizes a mechanical extensometer, while the other uses an ultrasonic transducer. The mechanical extensometer may be used in high humidity and dusty areas that can affect the accuracy of the ultrasonic transducer. The ultrasonic unit, which does not obstruct the traffic in a mine, may be used in high-traffic, low-humidity, low-dust areas of the mine.

The mechanical closure-rate instrument consists of a rugged telescoping potentiometric extensometer and an electronic digital readout-control box which displays the accumulated closure and the rate of closure. The extensometer is designed to accommodate an opening height of from 4.5 to 12 ft, with a measurement range of 6 in.

The ultrasonic closure-rate instrument uses an ultrasonic transducer to measure the traveltime of an ultrasonic wave that is emitted from the transducer installed at the roof and reflected back to the roof transducer from the floor. A readout device then translates the ultrasonic signals into the roof-to-floor closure and the rate of closure. To make use of the instruments for roof fall hazard prediction the mine operator must predetermine the critical rate of closure for each particular mining location. Once this is done, the instrument can be



A telescoping closure-rate extensometer (bottom), which has a 6-in measurement range in openings of 5 to 12 ft, is connected to a closure-rate readout instrument (top) to give warning of an imminent roof fall by providing the amount and rate of roof-to-floor closure.

set to trigger an audiovisual alarm at the critical closure rate to warn the mine workers of impending roof fall in the vicinity of the instrument.

The mechanical instrument was tested successfully in predicting roof caving during a pillar extraction operation in the Southern Utah Fuel Company No. 1 mine near Salina, Utah. The ultrasonic instrument is being fabricated for field evaluation.

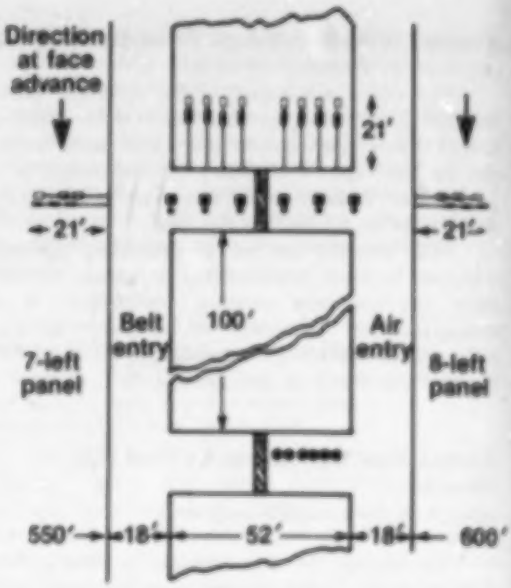
Longwall Mining Design Parameters

Paul H. Lu, Principal Investigator
Denver Research Center, Denver, Colo.

Design of an optimum mine system requires realistic and precise values of design parameters that are determined in situ by measuring existing ground pressure, mining induced load transfer, strata movement, deformation modulus, and rock strength in operating mines. Practical and inexpensive techniques of determining the basic design parameters for a longwall mining panel have been developed by the Bureau. Case studies have been made at six coal mines. The required instruments are simple, inexpensive, and in some cases expendable. They include hydraulic pressure recorders.

Existing ground pressure is determined by a combination of one cylindrical and two flat hydraulic pressure cells installed in a single borehole. Mining induced load transfer and progressive chain pillar loading profiles are measured by preencapsulated flat, hydraulic pressure cells installed in boreholes. Residual pillar strength is estimated from the measured horizontal pillar pressure, and vertical pillar pressure is directly measured with flat pressure cells.

The pillar integrity factor, defined as the ratio of the integrated total residual strength to the integrated total vertical load of the cross section of a given pillar, is a rational parameter for stability evaluation and design of chain pillars. The magnitude and the width of pressure abutment, which are determined from the load transfer measurement using preencapsulated borehole pressure cells, may be used as the criteria for the gate-entry support design. Differential roof and floor strata movement and bed separation, which are monitored by the automatic recording multiple-point extensometers, are useful parameters for the design of face and roof supports and floor control. The roof-to-floor convergence, measured with automatic recording convergence meters, is the most commonly used mine design parameter. The modulus of rigidity,



Schematic showing an instrumented chain pillar and mining progress.

which is determined by borehole dilation tests with a cylindrical hydraulic pressure cell, can be readily converted to the deformation modulus, which is needed for mine structural design and analysis.

Industrial Hazards

Intrinsically Safe Monitoring System

T. J. Fisher, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

If mine monitoring systems for gassy mines are to be useful and reliable even under emergency conditions, they must have an intrinsically safe, uninterruptable power supply and intrinsically safe sensors. Such an intrinsically safe mine monitoring system has been developed by the Bureau. Powered by a source of electricity independent of the mine power supply, the system can function

A carbon monoxide monitor that forms part of an intrinsically safe, whole mine monitoring system is checked.

even when the mine power must be shut off, as during a loss of ventilation.

Currently the system is installed at the Helvetia Coal Co. Lucerne No. 8 Mine near Johnstown, Pa. Two intrinsically safe trunklines are connected to methane, carbon monoxide, and airflow transducers located throughout the mine. A microprocessor-based central station displays information in the mine office safety room. Data are displayed on a cathode-ray tube and are recorded on two printers. The initial installation involves 15,000 ft of cable spanning five working sections. Connection of monitoring points to the system is simplified by a distributed cable layout. Five transducers monitor carbon monoxide along the beltways, three monitor methane at transfer points, and five other transducers provide the operator with airflow measurements along various airways. Transducers are calibrated monthly and checked weekly. A portable calibration kit and an approved digital voltmeter simplify the 20-min calibration and 10-min check procedures. Performance of the

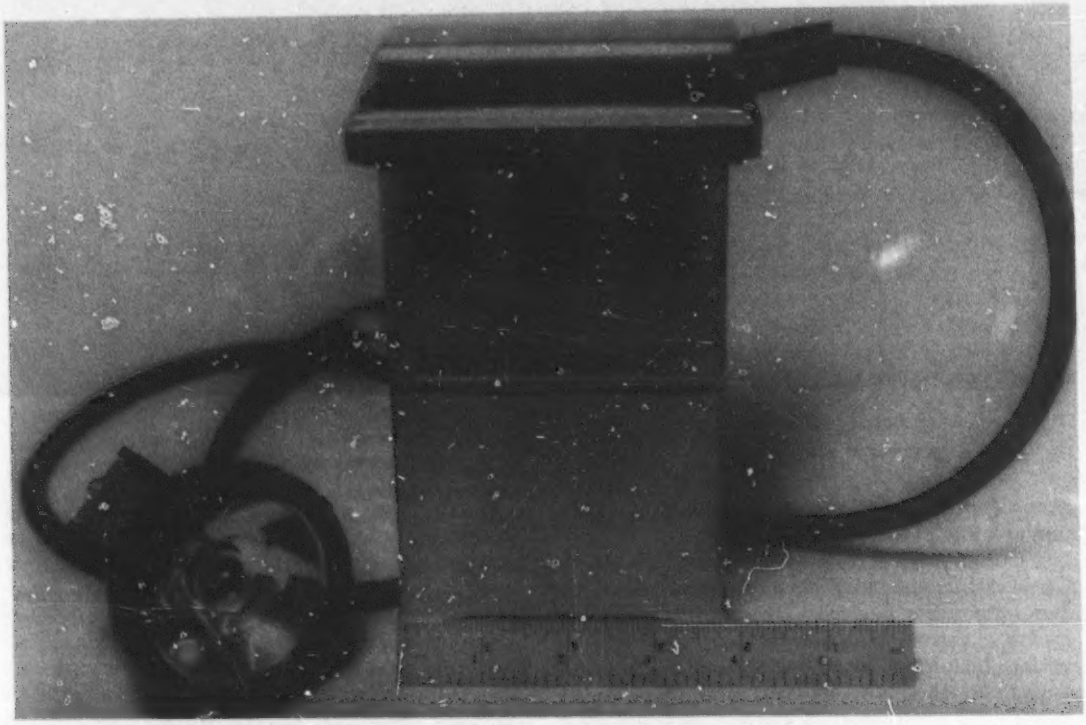
system to date has been acceptable. Expansion into fan, pump, belt, and switchgear monitoring is planned.

Improved Personal Lighting System—Advances in the Miner's Cap Lamp

W. H. Lewis, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

The miner's cap lamp and battery system in present use has long been a highly reliable and indispensable device, and has undergone few changes in its many years of existence. Recent advances in battery technology, however, have made additional improvements possible. A new nickel-cadmium cap lamp battery, developed by the Bureau, offers a 48-pct reduction in weight (2.42 versus 4.66 lb) and a 15-pct reduction in volume, as compared with existing lead acid batteries. The charging cycle life has also been increased. Although testing is still underway, a charging cycle life of 1,000 cycles is expected; this could extend the useful life of the battery to 3 to 4 years of normal use.

The new battery has been designed to be compatible with existing lead-acid charging systems, which eliminates the need to replace charging equipment when phasing in the new batteries. The present cost of the nickel-cadmium battery is $50.00 as compared with $30.00 for the lead-acid battery. However, the expected life of the new battery is 1,000 charge-discharge cycles as compared with 400 cycles for the existing lead-acid device, resulting in a lower operating cost. Additional features being incorporated into the cap lamp headpiece should also enhance the system's marketability. A new reflector has been designed to accept both the new tungsten-halogen type bulb and the conventional dual filament incandescent. The new bulb offers the equivalent light output of the conventional incandescent bulb, but with reduced power consumption and greater life; because it has only one filament, two bulbs will be used as a fail-safe feature. Elevation of the headpiece assembly will allow some directional control of the light beam; this should be particularly useful in very low coal and for miners who wear bifocal eyeglasses. Other safety features being



Use of a nickel-cadmium battery in a miner's cap lamp instead of a lead-acid battery gives a 48-pct reduction in weight and a 15-pct reduction in volume.

considered are a coiled battery cord and a cord disconnect mechanism.

Defining Illumination Requirements for Underground Metal and Nonmetal Mines

J. M. Peay, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Good lighting is important to the underground miner. It reduces accidents, improves morale, and increases productivity. However, typical industrial lighting standards and practices are often inappropriate in the underground environment, owing to economics, the unique combination of confined space and extensive worker mobility, and the need to maintain the worker's adaptation to low-light levels. Recognizing this, the Bureau undertook a major research effort to determine minimum luminance levels necessary for safe performance of critical mining jobs, and to formulate effective illumination standards for underground work. Such standards have been developed for coal mines and are being implemented by the coal mining industry.

Typical lighting, with excessive glare, in an underground noncoal mine.

Similar standards must now be established for underground metal and nonmetal mines.

A survey of jobs and work locations in these mines to determine the visual requirements and current lighting practices revealed the great variability that exists in underground metal and nonmetal mining, not only between mines but within a given mine. Underground work areas differ significantly in size of openings (both height and width), reflectance of underground surfaces, output of luminaires, and types of impairment to vision. Perhaps the most significant finding is the wide variety of jobs performed at any given work site. Moreover, there is no apparent relation between the difficulty of the visual tasks being performed and the luminaires being used. Jobs with difficult visual demands are just as likely to be performed with cap lamps alone, as with high-output luminaires. It was concluded that the work site itself should be the primary focus of illumination recommendations.

Accordingly, the current emphasis is on the minimal luminance levels required for safe performance of the visual components of safety-critical mining jobs. Performances of these critical visual tasks are being tested under varying levels of illumination to determine the lowest level necessary for correct performance of the visual task. Results to date indicate that, in general, the amount of light is only one critical factor in underground illumination. Equally important are the distribution and direction of light at the work place. Thus, luminance may need to be increased in certain parts of the working area but not in others. Other important considerations are glare, light scattering due to aerosols, temporary blindness from exposure to bright light, and visibility losses because of dirty protective eyewear. Recognition of the special visual requirements of older workers is also important in developing recommendations for good mine lighting practices.

Whole-Mine Medium Frequency Communications

H. Dobroski, Jr., Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

A medium frequency (MF) radio communication system has been developed and tested in several underground mines. It offers a unique solution to mine wireless communications because of its ability to couple into, and reradiate from, existing mine wiring such as power cables and trolley lines.

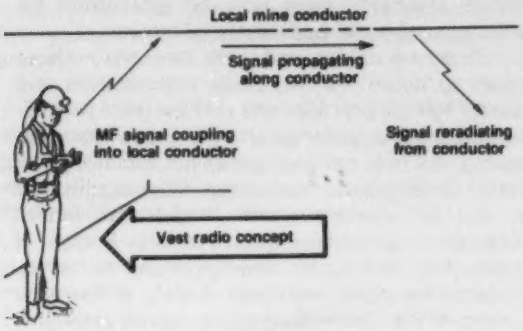

Local mine conductor
Signal propagating along conductor
MF signal coupling into local conductor
Signal reradiating from conductor
Vest radio concept

Illustration of the principle of medium frequency (MF) radiowave coupling and reradiation via conventional mine wiring.

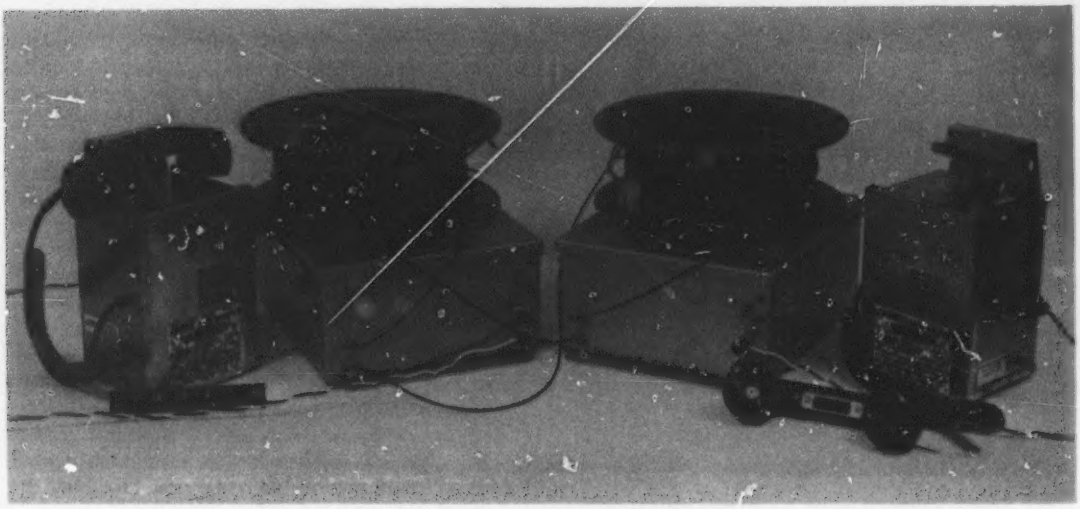
Fixed and mobile transceivers utilize existing mine wiring. The fixed transceivers (base stations and repeaters) use special signal couplers, attached around local mine wiring, that can be installed in minutes. The wiring used becomes the antenna system for the base station or repeater; other wiring, not connected to the couplers, also becomes antennas. In this way, almost every conductor in the mine at least partially benefits the system. In practice, the base stations are usually placed near a portal or dispatcher-mine office; the repeaters are in a main entry where prime power is available, and the associated coupler has access to additional mine wiring.

The mobile transceivers are designed for vehicles and personnel. The vehicular units use small loop antennas that allow them to reach to the nearest local mine wiring. The personal units are smaller and are part of a vest design that results in a very low profile. The mobile transceivers can maintain direct contact by standard radio means or indirect contact by repeater action. They can also communicate with any base station. To date, performance under the harsh conditions of underground mines has been very good. The MF system also offers useful communications range in coal mines where no wiring is present. This involves a "coal seam" mode of propagation, in which the MF signal is guided by high conductivity roof and floor rock and low conductivity coal; both these conditions are necessary for propagation.

Fiber Optic Technology in Underground Mines

H. Dobroski, Jr., Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Over the last decade, there has been a significant increase in the use of fiber optic communications, principally by the telephone industry which has applied the technology primarily to long distance interoffice trunklines. Fiber optic communications systems use cables composed of glass strands to transmit signals rather than the traditional wire. To date, little use has been made of fiber optics on local networks, such as underground mine communications systems, because of high cost and complexity. However, fiber optics offers a



Fiber optic pager phone system uses glass-strand cable instead of traditional wire to transmit signals.

number of potential advantages over wired systems, that would be of benefit to the mining industry. These advantages include the absence of electrical signals which insures intrinsic safety, immunity to electromagnetic interferences (EMI), large bandwidth which increases the data storage capacity, and low weight. To determine the feasibility of applying fiber optic technology to underground mine communications, the Bureau undertook a study of the benefits and disadvantages of such application, including development and evaluation of a prototype system.

It was shown that fiber optic technology would offer advantages to communications and monitoring in underground mine situations where its unique characteristics are of prime importance. For instance, fiber optic cables could be run into the working face, return air, or gob areas without the danger of electrical explosions. Gas could be monitored by passive sensors located in hazardous areas, with the active monitoring system components (light sources and gas analyzers) located remotely in areas where no gas ignition hazards exist. Very long fiber optic cables could be run between sensors and locations of high EMI, without signal degradation. Very high data rate systems would be possible between in-mine sites and data analysis centers on the surface.

Fiber optics is a relatively new technology that has not yet been applied to the mining industry on any scale. Costs are generally relatively high, and skilled installation and maintenance are required. However, costs continue to decline, owing to technological advances and increased production. This, coupled with training and the advantages that fiber optics offers, can result in numerous future fiber optic systems for the mining industry.

Explosionproof Enclosure Research

L. W. Scott, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

To permit designers of explosionproof enclosures more design freedom and opportunity for innovation, performance standards have been developed by the Bureau that will insure the same

Hydrostatic testing of explosionproof enclosure is monitored using strain gages (center) and a pressure transducer (right).

degree of safety as the present Federal requirements. These new standards which provide a method for the approval and certification by the Mine Safety and Health Administration (MSHA) of explosionproof enclosures for use in gassy mines are based solely on the performance of the enclosure during specified tests. Structure integrity is evaluated by a structural performance test, which actually involves two tests. One test is similar to the present internal methane-air explosion test in that it verifies that the enclosure would not transmit an explosion to a surrounding methane-air atmosphere. The other test, a hydrostatic pressure test, will verify the structural integrity of the enclosure by internal pressurization to 300 pounds per square inch.

Guidelines for windows and lenses used in explosionproof enclosures have also been developed. These guidelines include procedures for the design of glass and plastic windows, and their mounting and seating arrangements. At the present, only glass and polycarbonate plastic are qualified for windows in explosionproof enclosures, however procedures for qualifying new plastics have been developed. Acceptance criteria for adhesives and sealants also have been developed by the Bureau and have been adopted by MSHA for its approval and certification program. New safe electrical clearances for high-voltage enclosures have also been established. These new clearances should prevent dangerous arc discharges from occurring in the event of an internal methane-air explosion.

To make the results of this research available to industry, the Bureau is preparing a design guide for explosionproof enclosures. The guide will address those aspects of design that affect enclosure strength and ruggedness. Its purpose is to provide guidelines for the design of explosionproof enclosures which, if followed, will assure that the enclosure will meet both MSHA certification and testing requirements, and service life requirements underground.

Formalizing Occupational Training

W. Wieghagen, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Accident studies show that workers assigned to unfamiliar tasks have a higher probability of injury than veteran workers. Recognizing that structured training for occupational skills can greatly accelerate the acquisition of production and safety skills, the Bureau has been engaged in developing generic materials for a wide variety of occupational training. These materials consist of self- or classroom-administered trainee materials, and procedures for conducting on-the-job training. Developed materials have served as a foundation for many industrial trainers to build on and to upgrade their own training. To date, guides have been developed and distributed for hoist equipment, haulers (diesel mechanical), preshift inspection of equipment, mine rescue operations, and blasting of surface coal. Similar guides are in preparation for shuttle cars, roof bolters, continuous miners used underground; for diesel-electric haulers, front-end loaders dozers, scrappers, drills, graders, utility vehicles, hydraulic excavators used in surface mining; and for certain special mining skills. By providing basic documentation (task analyses, performance criteria and course material), individual companies can incorporate site-specific information to achieve more measureable, performance-based programs.

Formalizing Health and Safety Training

W. Wiehagen, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Mining is an inherently hazardous occupation and provisions must be made for ensuring proper performance in emergency situations. This means, among other things, developing contingency skills that are not normally reinforced through the day-to-day work activities. The Bureau has been addressing this need through the development of instructional guides detailing training objectives, methods, and evaluation procedures for training elements required by Federal regulations for new hires and veteran workers. Developed materials include instructional guides for surface and underground coal, deep metal and nonmetal, sand and gravel, underground salt, open pit, and surface and underground uranium. New-hire and annual refresher training materials are serving as resources for industrial mine trainers in preparing and conducting mandated training. These materials can also be a starting point for the longer term goal of developing health and safety information and performance criteria. These criteria, along with trainee evaluation procedures, can be used to verify an individual miner's knowledge and performance capabilities. Wide distribution of the guides is being assured by the Mine Safety and Health Administration.

The following is a tabulation of the material available for training elements required for new hires and veteran workers.

Topic	New miner	Newly employed and experienced miner	Annual refresher
UNDERGROUND: COAL, DEEP METAL-NONMETAL, URANIUM, AND SALT MINES			
Statutory rights and responsibilities of supervisors	X	X	
Self-rescue and respiratory devices	X		X
Entering and leaving the mine transportation; communication	X	X	X
Introduction to the work environment	X	X	
Mine maps; escapeways; emergency evacuation; barricading	X	X	X
Roof and ground control and ventilation plans	X	X	
Health	X		X
Cleanup; rock dusting	X		
Hazard recognition	X	X	
Electrical hazard	X		X
First aid	X		X
Mine gases	X		X
Health and safety aspects of assigned tasks	X		
Mandatory health and safety standards		X	X
Prevention of accidents			X
Explosives			X

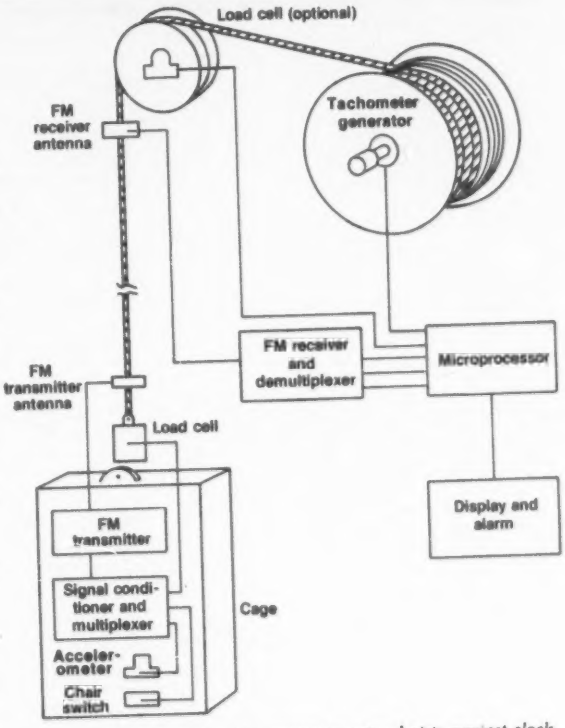
Topic	New miner	Newly employed and experienced miner	Annual refresher
SURFACE: COAL, SAND AND GRAVEL, AND METAL-NONMETAL MINES			
Statutory rights and responsibilities of supervisors	X	X	
Self-rescue and respiratory devices	X		X
Transportation and communication	X	X	X
Introduction to the work environment	X	X	
Escape and emergency evacuation; fire warning and firefighting	X	X	X
Ground control; highwalls, water hazards, pits and spoil banks illumination and nightwork	X	X	X
Health	X		X
Hazard recognition	X	X	
Electrical hazard	X		X
First aid	X		X
Explosives	X		X
Health and safety aspects of assigned tasks	X		
Mandatory health and safety standards		X	X
Prevention of accidents			X

Slack and Overload Rope Protection System for Mine Hoists

E. Ayres, Principal Investigator
Pittsburgh Research Center, Pittsburgh, Pa.

Hoists used to transport personnel and material in deep underground mine shafts must operate safely, despite heavy loading and a hostile environment. One potential problem is that the conveyance may lodge against its guides while moving, causing a slack or overloaded rope. Sudden starts and stops can also cause excessive dynamic force variations. To prevent these unsafe conditions, the Bureau has developed an instrumentation package to monitor the hoist operation continuously.

The system operates on the principle that the force of the unknown obstruction can be calculated by taking the scaled difference between the rope tension at the cage, as measured by a fail-safe load cell, and the acceleration of the cage. When this difference exceeds a specified value, an alarm is triggered and corrective action can be taken. Sensors for drum speed, headsheave bearing load, and cage chair position provide additional data for the microprocessor-based system, making it possible to detect a variety of adverse conditions (overload, slack, overspeed, excessive vibration, etc.) before they become major. The resulting system is adaptable to vertical and sloped shafts,



Schematic of a system for protecting mine hoists against slack and overloaded ropes.

and will perform safely and reliably underground. A prototype system is being evaluated at a mine in Colorado.

Analytical Investigation of Deep Shaft Wire Rope

Grant L. Anderson, Technical Project Officer
Spokane Research Center, Spokane, Wash.

The mining industry is heavily dependent on wire rope for hoisting personnel, materials, and ore. The safety and economics of hoisting requires rope to be highly reliable. This reliability must be maintained under a broad range of operation conditions (different loads, drums, sheaves, etc.) and severe environmental conditions. Rope and wire stresses resulting from various equipment configurations and loads are difficult to determine because comprehensive analysis procedures have been lacking. As a result, estimates of performance and service life, and optimum rope selection cannot be easily made. Therefore, rope selections are presently made on the basis of field experience and accelerated testing by manufacturers.

The Bureau has derived a mathematical solution for individual wire stresses within a wire rope subjected to a combination of axial loading and bending over a sheave. Equations for dynamic loading associated with acceleration, deceleration, and filling a skip have also been derived. The equations calculate tensile, torsional, shear, bending, and contact stresses for individual wires. All wire stresses are combined to obtain the overall rope behavior.

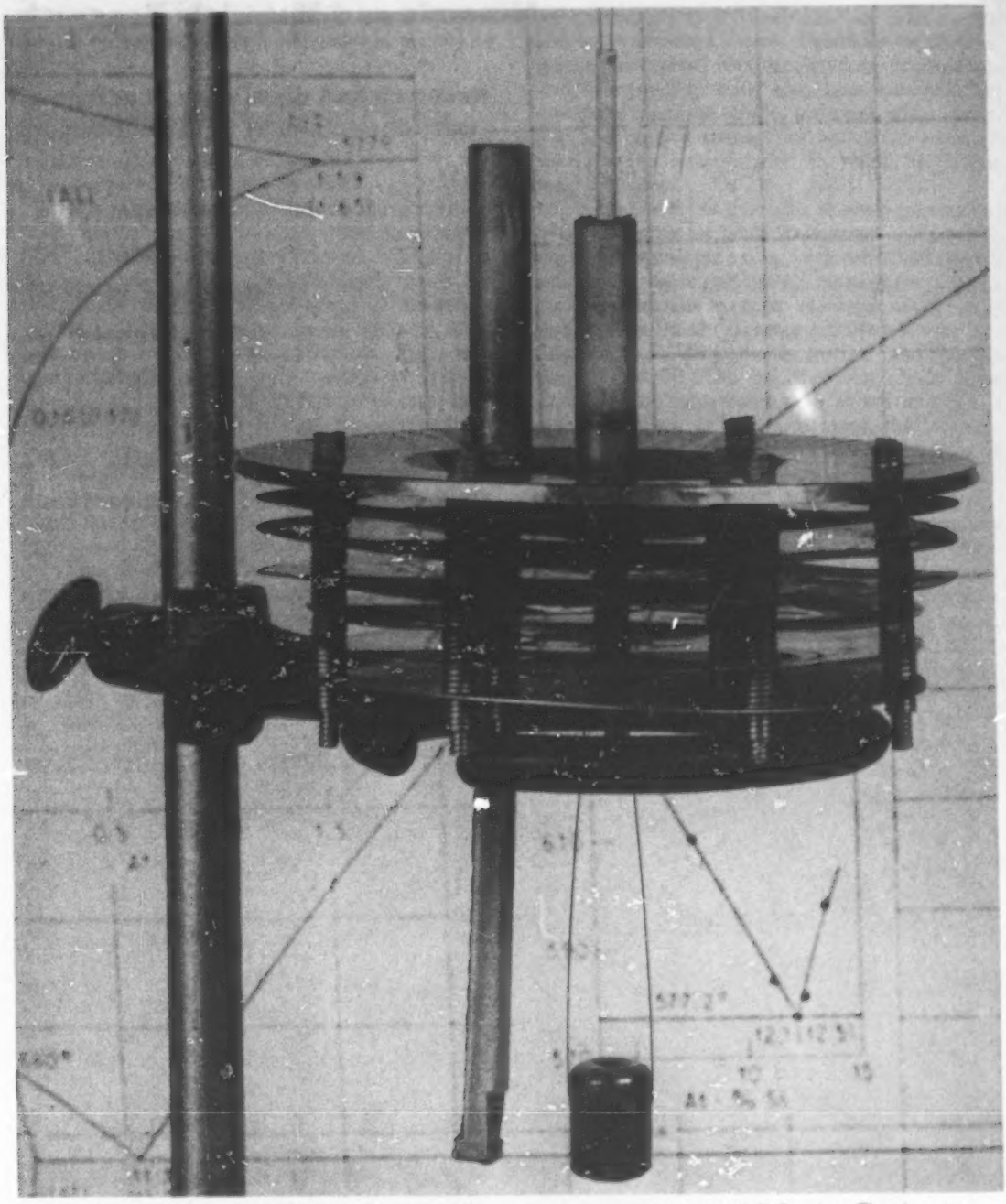
Analyses show that wire stresses are reduced as the number of wires in a rope is increased. Bending stresses for a 6 by 19 construction rope (6 strands, 19 wires per strand) increases rapidly for sheave diameter to rope diameter (D/d) ratios smaller than 20 or 30; however, there is very little decrease in bending stresses for D/d ratio changes from 70 to 90. The greatest wire elastic stress occurs in the center wire of a strand at low D/d ratios; however, at large D/d ratios, the independent wire rope core center wire is the highest stressed. Some of these behaviors have been recognized from field experience.

The equations have been coded for computer solution and can be used to optimize rope construction, and sheave or drum diameters, and permit estimates of performance and service life.

Minerals and Materials Research

Research and development activities were conducted at field facilities in:

Albany, Oreg.,
Avondale, Md.,
Boulder City, Nev.,
Reno, Nev.,
Rolla, Mo.,
Salt Lake City, Utah.
Tuscaloosa, Ala.,
and Twin Cities, Minn.



Apparatus for equilibrating aluminum-silicon alloys with carbon or the various carbides in the Al-Si-C system. The elements are contained within graphite or carbide crucibles that are enclosed within tantalum capsules by arc welding. The capsules are suspended within a high-temperature furnace by tungsten-rhenium thermocouple wires that are also used for temperature measurement. The upper multilayered assembly is part of the furnace heat shields.

High-Temperature Thermodynamics and Kinetics

L. L. Oden, Principal Investigator
Albany Research Center, Albany, Oreg.

The direct smelting of alumina with carbon, as an alternative to the traditional Bayer-Hall process, has eluded commercialization for nearly 100 years. The many false starts in pilot and small commercial operations and the voluminous patent and scientific literature on the subject attest to the resourcefulness and tenacity of researchers in the field.

Two very important problems that have not been adequately solved are excessive recycle of aluminum carbide resulting from carbon solubility in product metal and vaporization of aluminum and intermediate reaction products at the high temperatures required for carbothermic reduction. It is generally conceded that another metal oxide must be cosmelted with alumina to reduce the activity and hence the vaporization of aluminum. The oxides of Cu, Fe, and Si have been used with varying success. Silicon is the most appropriate because it has a high boiling point (2,600° C). Combinations of silicon dioxide with aluminum oxide occur in nature in almost unlimited quantities, and alloys of aluminum and silicon are themselves very useful.

Except for the binary subsystems, little is known of the ternary Al-Si-C system, and the Bureau of Mines is conducting research to fill that void. The liquidus surface, the 2,000° C isothermal section, and the vertical section through Al_4C_3 and SiC are three constructions that would adequately characterize the ternary system. The liquidus surface indicates the solubility of carbon in liquid aluminum-silicon alloys; the isothermal section is in the temperature range of the metal-producing reactions that occur during carbothermic reduction, and the vertical section through Al_4C_3 and SiC contains all of the reported complex carbides in the ternary system.

The vaporization of aluminum and intermediate reaction products in the quaternary Al-Si-C-O system is being studied also using a Knudsen effusion cell and mass spectrometry. Vapor species are being identified and vapor pressures are being measured as a function of temperature.

Particulate Mineralogy

William J. Campbell, Principal Investigator
Avondale Research Center, Avondale, Md.

By combining expertise in mineralogy, geology, and chemistry with state-of-the-art analytical methods, the Bureau provides expert technical assistance on mineral particulate-related problems to organizations in both the public and private sectors.

Regulatory agencies are giving increased attention to the identification of mineral particulates that may produce adverse health effects as a result of occupational or environmental exposure. The Bureau has been actively involved in the identification and characterization of fibrous mineral particulates to protect both the worker and the public, and to assure that overregulation does not adversely impact the domestic supply of minerals. According to Mine Safety and Health Administration (MSHA) studies, over 6,200 mines in the United States have been identified as potential sources of asbestos using the present regulatory definition of asbestos. Therefore, the definition of asbestos and the counting criteria used by regulatory agencies is of paramount importance to the domestic mining industry.

Well-characterized fibrous and blocky mineral samples were provided by the Bureau for oral-ingestion animal studies by the National Institute of Environmental Health Sciences. Rats and hamsters fed particulate materials as part of their diet showed no significant differences from control-fed animals, suggesting that regulations for ingested fibrous minerals were not as critical as anticipated. These studies relate to the concern over taconite tailings deposited in Lake Superior, and release of asbestos from asbestos concrete pipe used in major urban water supply systems.

Until recently, the emphasis in health-related research had been placed on three asbestos minerals of commerce—amosite, crocidolite, and chrysotile. Attention now is being given to all fibrous minerals. For example, erionite, a zeolite mineral, occurs in various habits ranging from the common blocky variety to a rare asbestiform variety. Zeolites from deposits in the Western United States were examined, and their size-shape characteristics were compared with amphibole asbestos. Only the rare wooly erionite variety has a fibrosity similar to asbestos. The more common erionite and mordenite zeolites can occur in acicular habits similar to amphibole cleavage fragments. However, the most common zeolites crystallize in blocky forms.

Studies recently were completed on amphibole particles collected on personnel air monitors by MSHA and Occupational Safety and Health

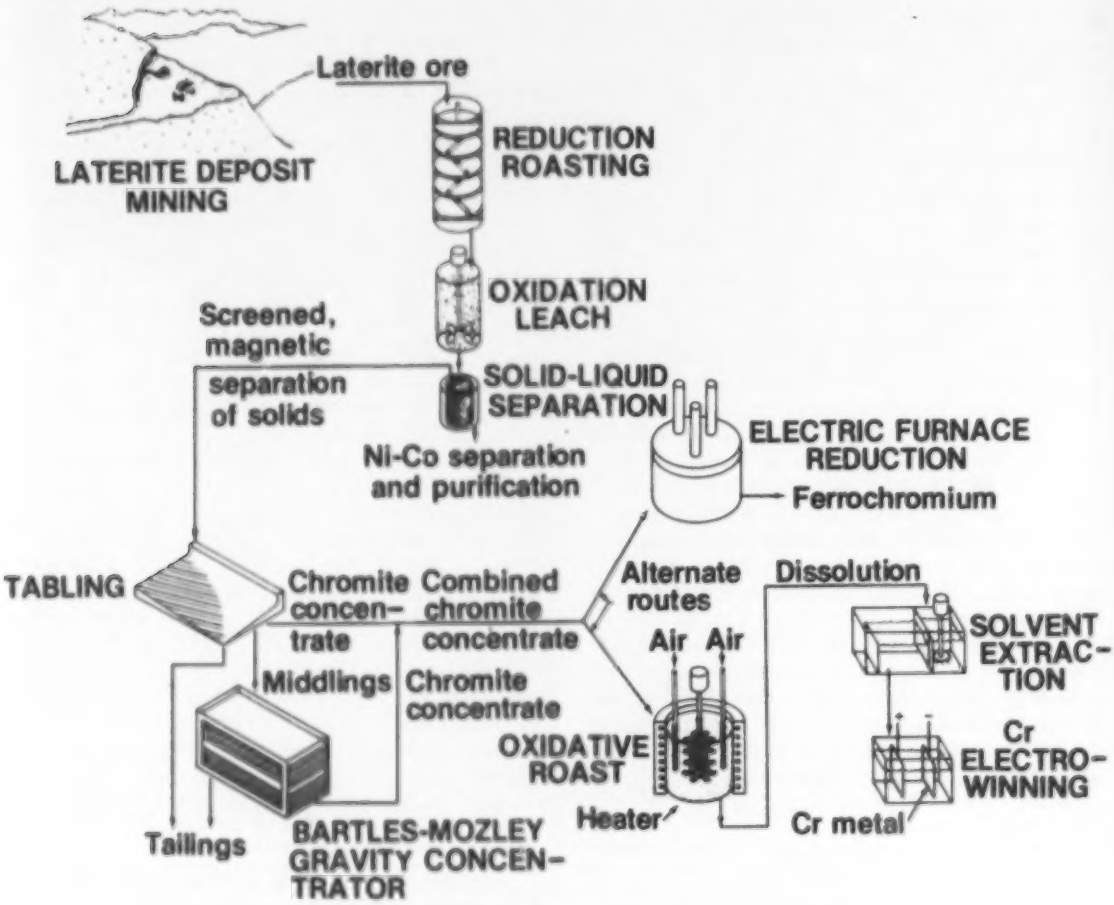
Administration personnel at mining and industrial sites, respectively. These types of data are necessary for the health scientists to assess the potential hazard of cleavage fragments and fibers.

Close cooperation with the Department of Health and Human Resources; participation in workshops of the National Bureau of Standards, EPA, MSHA, American Ceramic Society, and the Society of Occupational and Environmental Health; and technical reviews of mineralogical and analytical position papers assures strong interaction with other researchers involved in mineral particulate studies and those responsible for regulating exposure to mineral particulates.

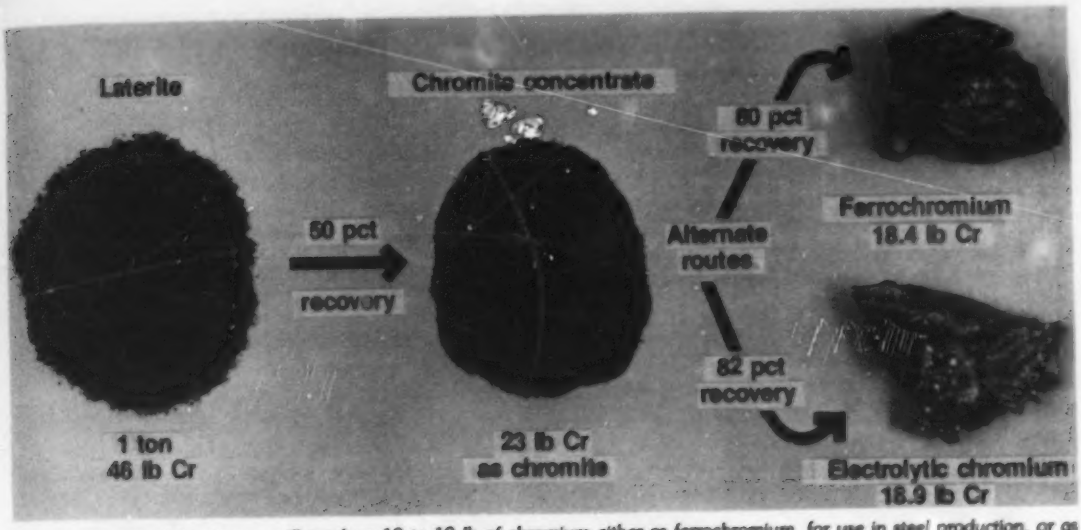
Chemical and Physical Enhancement of Domestic Chromites

R. E. Siemens, D. N. Nilsen, and D. E. Kirby, Principal Investigators
Albany Research Center, Albany, Oreg.

Substantial quantity of chromium in the form of very low-grade chromite occurs in association with the nickel and cobalt resources in the laterite deposits that lie along the border of Oregon and California near the Pacific coast. Although the deposits are too low in grade for economic recovery of any one of these critical metals, the combined recovery of all three metals could offer an economic advantage in processing domestic laterites.



Procedure for recovering chromium from low-grade domestic laterites.



Processing 1 ton of laterite ore will produce 18 to 19 lb of chromium either as ferrochromium, for use in steel production, or as electrolytic chromium.

Past Bureau of Mines research concentrated on perfecting a method of processing the laterites for the nickel and cobalt recovery. Technology was developed that incorporates selective reduction with carbon monoxide followed by an oxidizing ammonia-ammonium sulfate leach. Solvent extraction followed by electrowinning recovers high-purity nickel and cobalt from leach solution. This procedure has more potential economically than conventional technology because metal recovery is higher, particularly with respect to cobalt.

Research now is focused on recovering the associated chromium after the laterites have been processed to recover nickel and cobalt. The remaining residue is upgraded by gravity concentration. The concentrate contains about 35 pct Cr_2O_3, and can be processed further either in an electric furnace to produce ferrochromium or by a caustic soda roast-leach procedure to extract pure chromium. Preliminary extraction results indicate that over 80 pct of the chromium can be recovered by either approach.

In a Bureau-developed pyrometallurgical process for the production of ferrochromium, the flour-sized concentrates are processed without agglomeration by feeding them to an electric furnace together with wood chips. The chips prevent the chromite from being blown out of the furnace, provide porosity in the charge to allow gases to escape, and provide a partial source of reductant. By using this technology a separate prereduction step is not required for the production of ferrochromium.

Because the chromite derived from laterites contains higher levels of impurities such as silica, alumina, and magnesia, it is not amenable to conventional chemical processing to produce purified chromium products. These impurities cause handling problems when the chromites are roasted and result in decreased chromium recovery. To overcome this problem an alternate approach is being investigated wherein the domestic chromites are roasted with caustic soda at a lower temperature instead of with soda ash. This technique alleviates the handling problems caused by impurities, and should overcome objections to using a higher cost reagent by providing for recycle of the caustic soda.

Appraisal of Critical Minerals From Northwestern and Alaskan Resources

Laurence L. Brown, Principal Investigator
Albany Research Center, Albany, Oreg.

There is virtually no domestic production of strategic and critical minerals such as those containing chromium, cobalt, platinum, columbium, tantalum, and tin. This requires that these commodities be purchased in the world market, which makes the United States vulnerable to supply disruptions or price increases that could have serious national security or economic implications.

Samples containing critical minerals are taken from deposits in remote areas for characterization and beneficiation studies. Here, samples are being obtained from deposits near the Arctic Circle in central Alaska.

Much of Alaska, and to a lesser extent the mountainous areas in the Pacific Northwest, has not been explored thoroughly for its mineral content. The varied and complex geological environments of these regions are similar in many respects to those that occur worldwide and that are known to contain deposits of strategic and critical minerals. To assess the minerals of these areas, the Bureau of Mines has undertaken a systematic program to identify deposits, characterize the ores, and to investigate technology for recovering the mineral values discovered.

In cooperation with Bureau Field Operations Centers, the systematic appraisal of a mineral occurrence is begun with a geological investigation of targeted areas. The most promising site-specific zones within these areas are given an onsite surface study to develop a preliminary assessment for the mineral content. Bulk samples then are taken from those sites identified as having the best potential for mineral recovery.

Initially these samples undergo detailed laboratory mineralogical and physical examinations. Minerals are identified and their composition, association, and size range are determined. Analytical methods are used to further characterize the materials, and samples that show promise from these screening studies are appraised further by detailed beneficiation studies. Various mineral separation and recovery schemes are studied by applying crushing, grinding, and screening methods. Finally, gravity, electrodynamic and froth flotation separation techniques are used to recover individual mineral products that can be evaluated for metallurgical processing.

Joint studies thus far have led to definitive reports on platinum-group metal occurrences in southeastern Alaska and on chromium occurrences in north-central Alaska. Current studies are focused on potential chromium-bearing materials in south-central Alaska and on potential cobalt, nickel, and platinum-group metals in southeastern Alaska.

ead Production by Hydrometallurgy and Molten-Salt Electrolysis

I. A. Eisele and J. E. Murphy, Principal Investigators
Reno Research Center, Reno, Nev.

Lead smelter operators face the possibility of more stringent lead exposure standards being promulgated and, in addition, must address the continuing problem of sulfur dioxide emission to the atmosphere.

As a means of avoiding these problem areas, a hydrometallurgical alternative to smelting was investigated on a bench scale. In this method, galena concentrate was leached with a hot ferric chloride-sodium chloride solution to dissolve lead chloride and discharge the sulfur as elemental sulfur. The crystallized lead chloride was electrolyzed in a molten-salt cell to produce lead metal and chlorine gas. The chlorine was used to oxidize the iron content of the leaching solution to ferric chloride for reuse in the leaching step.

The Bureau, under a cost-sharing cooperative research program with four major lead producers, investigated the leaching-electrolysis method in a process development unit designed to produce 500 lbs of metal per day. The operation demonstrated that (1) commercially available materials, such as polymers and titanium, can withstand the corrosive chloride solutions, (2) 99.999 pct lead metal can be produced with an energy consumption of 0.5 kwhr/lb (kilowatt-hour per pound) of lead, and (3) lead exposure in the workplace meets OSHA standards.

Additional research is needed to better define the process and to investigate means of decreasing

A hydrometallurgical alternative (leaching-electrolysis) to lead smelting is investigated in a process development unit.

the electrolysis power consumption. Methods must be developed also for disposal of solid and liquid wastes.

Titanium Recovery From Domestic Perovskite Ores

M. B. Shirts, H. Dolesal, and D. A. Martin, Principal Investigators
Salt Lake City Research Center, Salt Lake City, Utah

Titanium is used in high-strength, high-temperature, and/or corrosion-resistant applications by industry and the military. Currently, there are no known substitutes for titanium in these applications. Rutile (TiO_2) is normally the starting mineral for producing the metal, however, U.S. reserves of rutile are extremely small and over half of the world's production of rutile concentrates is from Australia.

One of the largest single resources of titanium in the United States is a perovskite ($CaTiO_3$) deposit in Colorado. The 12-pct-TiO_2 ore can be upgraded by gravity concentration to contain 51 pct TiO_2, 2 pct rare earths, and 0.2 pct columbium. This concentrate, because of its high calcium content, is not suitable for treatment by conventional titanium metal production methods which involve high-temperature chlorination to titanium tetrachloride ($TiCl_4$) followed by reduction with magnesium or sodium.

The Bureau of Mines is evaluating methods for treating the perovskite concentrate to produce an acceptable starting product for metal production. One approach being investigated is a high-temperature chloridizing roast that converts the calcium to water-soluble calcium chloride. The leach residue, which contains the titanium, is low enough in calcium to be suitable as a feed to conventional chlorinators to produce $TiCl_4$. A second approach uses an acid leach of $CaTiO_3$ to extract the titanium. The solutions are purified and then a high-purity titanium product is precipitated. Extractions of up to 95 pct of the titanium have been achieved in a 40-min leach by this technique.

Tungsten Recovery From Searles Lake Brines

P. T. Brooks and P. B. Altringer, Principal Investigators
Salt Lake City Research Center, Salt Lake City, Utah

The rapidly growing use of wear-resistant tungsten carbide in well drilling and underground coal mining, and continuing uses in specialty steelmaking, superalloys, and chemicals make tungsten critical to our industrial economy. The United States depends on imports for over two-thirds of its annual tungsten requirements. Furthermore, most domestic resources of tungsten have been of little interest to commercial producers. Therefore, to help reduce import vulnerability, the Bureau of Mines has been conducting research to provide the basis for technology to recover tungsten from one of the largest low-grade domestic tungsten resources.

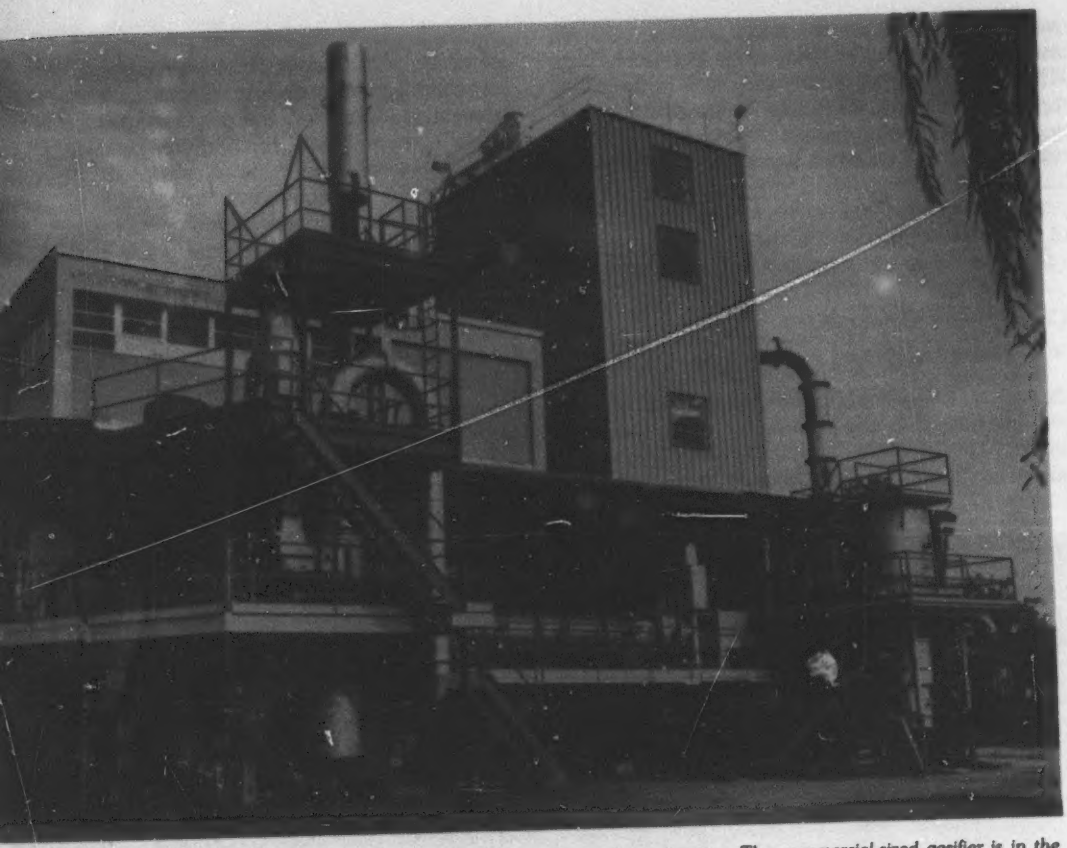
The brines of Searles Lake, Calif., contain an estimated 135 million pounds of tungsten; about one-fourth of the current U.S. reserves. While these brines are too dilute to process solely for tungsten, Bureau research has shown that it might be economically recovered as a byproduct during existing commercial processing that produces bromine, potassium salts, soda ash, salt cake, and boron chemicals. Key to recovery was the development of an ion exchange resin by the Bureau of Mines for sorption of tungsten. This potential process enabled tungsten recovery with minimum modifications to an existing plant. Through subsequent cooperative efforts with the commercial processor, Kerr-McGee Corp., feasibility of tungsten recovery on a commercial scale was shown. Using two stages of concentration by ion exchange, tungsten concentration was increased from 0.08 g/l (gram per liter) WO_3 in the brine to about 100 g/l WO_3 in the product solution. During tests at Searles Lake, the primary ion exchange unit extracted 90 pct of the tungsten from 5,000 gal of carbonated brine per day. Additional research effort is being directed toward developing basic technology for tungsten product recovery from the secondary eluate. Development of the process to improve economics will be left to the private sector.

Alternate Fuels for Mineral and Metallurgical Processes

John C. Nigro and Robert K. Zahl, Principal Investigators
Twin Cities Research Center, Minneapolis, Minn.

The increasing cost and lack of supply stability of both natural gas and oil have caused the Bureau of Mines to examine alternate fuels for mineral and metallurgical processes.

The Bureau, in cooperation with the Department of Energy (DOE) and 20 U.S. firms with interests in iron ore, coal, gas, and process design, has formed a cooperative, cost-sharing group known as the Mining and Industrial Fuel Gas group to promote development and demonstration of low-Btu coal gas as an alternate fuel for mineral processes and other industrial applications.



Pilot plant pelletizing facility used to evaluate low-Btu gas for iron ore pellet induration. The commercial-sized gasifier is in the background.

Performance tests have been conducted with a fixed-bed, 6.5-ft-diameter Wellman-Galusha gasifier installed at the Bureau's Twin Cities (Minn.) Research Center. The gasifier is owned by one of the industrial cooperators; the facility and construction were provided with Government funding; and operations, materials, and equipment are shared by all. Operation of the coal gasifier is the responsibility of the industrial cooperators. DOE is interested in gasifier operations and technology, while the Bureau is interested in demonstrating the use of the low-Btu coal gas as an alternate fuel for mineral and metallurgical processes.

Raw, low-Btu coal gas is being tested in the Bureau's pilot plant rotary kiln to demonstrate heat hardening of iron oxide pellets for blast furnace feed stock, as well as in a 21-ft-long combustion chamber to evaluate low-Btu gas burner designs. Eight different coals, including Kentucky bituminous, Colorado and Montana subbituminous, and Texas and North Dakota lignite, have been evaluated in the gasification-pelletizing tests since the program began. The work thus far has demonstrated that raw low-Btu gas can be used to indurate iron ore pellets. The research is now aimed at broadening the base of potential gasifier feed stocks and finding new metallurgical applications for the low-Btu coal gas.

The Environmental Protection Agency has monitored some of the tests to characterize various gaseous, liquid, and solid streams in the process in order to develop new source performance standards for low-Btu coal gasification.

Other elements of the alternate fuels program include the use of a 3-million-Btu/hr Bureau-designed cyclonic coal combustor for use in direct coal firing of western subbituminous and lignite coals. Preliminary test work has shown that over 90 pct of the ash in the coal combustion gases can be removed as a molten slag. High-temperature

mineral processes which cannot tolerate coal ash contamination could benefit from this technology. The cyclonic combustor also has potential to operate substoichiometrically for processes requiring hot gases with reducing potential. Research using pulverized coal in a cupola melting furnace is planned also. Previous Bureau research using natural gas has shown that the cupola capacity can be doubled with about 75 pct of the energy consumption and half the coke rate per ton of hot metal compared with conventional practice.

Materials and Recycling Technology

Use of Sulfur Concrete

W. C. McBee, T. A. Sullivan, and B. W. Jong, Principal Investigators
Boulder City Engineering Laboratory, Boulder City, Nev.

Metallurgical, chemical, and fertilizer industries in the United States sustain multimillion dollar losses annually due to chemical attack of plant structures. The majority of the damage results from continual attack of acid and salt solutions on reinforced portland cement concrete. These losses not only waste considerable quantities of steel, cement, and mineral aggregates, but also require extensive labor necessary for maintenance and repair.

Pouring a sulfur concrete floor slab in a new copper electrowinning plant in Arizona.

Modified-sulfur concrete material developed by the Bureau under a program to develop uses for plentiful domestic resources offers good promise for extended service life in severe corrosive industrial environments. As part of the program, sulfur concrete materials have been installed in 30 industrial plants for evaluation in 40 types of corrosive environments. These plants include metal production and refining operations for aluminum, copper, nickel, lead, manganese, magnesium, titanium, uranium, vanadium, zinc, and precious metals; and chemical fertilizer production plants for sulfuric, chromic, and nitric acids, and sodium and potassium salts.

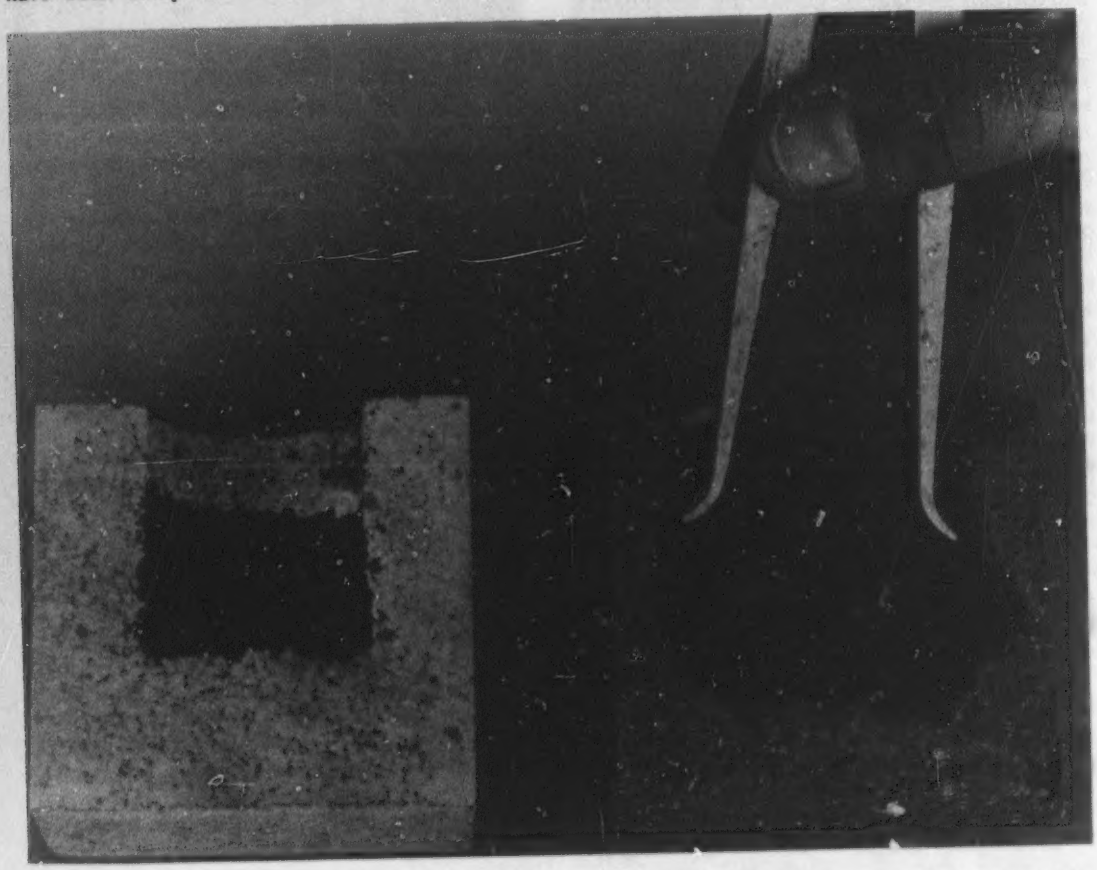
Material tests include precast components such as floor slabs, sump and weir tanks, pump foundations, electrolytic cells, and various sized test prisms and cylinders. Also, larger scale projects have been completed in which over 37,000 ft² (square feet) of sulfur concrete floor and several sumps ranging up to 2,000 gal capacity have been installed. These projects were conducted under cooperative agreements with four industrial companies.

Data from the industrial program have been very encouraging, with no component failures occurring in acid or salt environments after 4 years of use. Monitoring will continue to establish the ultimate durability and longevity of the material.

Substitutes for Refractory-Grade Bauxite

Hendrik Heystek and Arthur V. Petty, Jr.
Tuscaloosa Research Center, Tuscaloosa, Ala.

Alumina refractories made from refractory-grade bauxite (RGB) are used in a variety of high-temperature applications that involve metallurgical, glass, and cement processing operations.



In metallurgical processes involving high-iron slags, refractories containing less than 70 pct alumina are aggressively attacked (right) while refractories made from refractory-grade bauxite (more than 85 pct alumina) are not attacked (left).

Bauxite is composed primarily of one or more of the aluminum hydroxide minerals—gibbsite, diaspore, or boehmite. The requirements of RGB are very restrictive and require a minimum alumina content of 85 pct.

Inasmuch as most of the RGB used in the United States is imported, the Bureau of Mines is engaged in research to develop domestic resources as potential substitutes for imported RGB. Development of technology for using these domestic resources would decrease dependence on foreign sources, and provide a dependable and continuous supply of this refractory raw material that is important to our Nation's industry.

A research project has been undertaken in cooperation with the Alabama Geological Survey to evaluate saprolites as a source of alumina. Saprolite—a soft, weathered rock—occurs in a broad band from Virginia to east-central Alabama and contains fine-grained gibbsite and kaolinite in a complex mixture of silicate minerals.

Samples having gibbsite contents averaging 20 pct have been found in saprolites associated with weathered feldspathic hornblende gneiss. Preliminary Bureau research had indicated that such material could be beneficiated to provide a domestic source of a calcined 70 pct alumina that would substantially reduce the Nation's need for imported RGB.

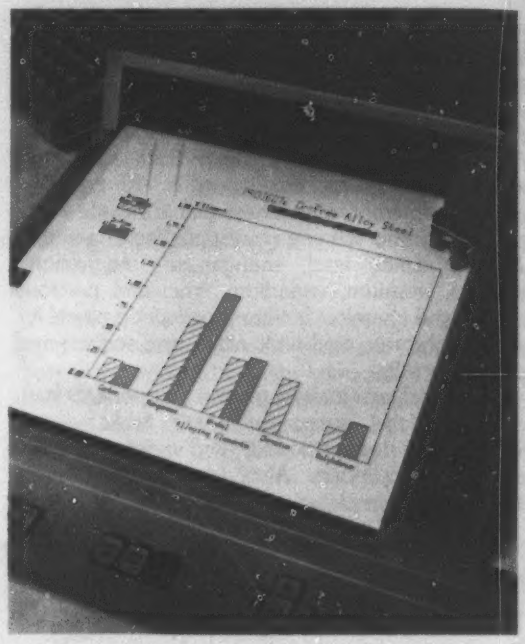
In other research efforts to find RGB substitutes, samples of high-alumina material prepared from waste aluminum dross have been evaluated. The high-alumina calcined product is composed of about 65 pct alpha-alumina with a magnesium aluminate spinel as the balance. Evaluations of the refractoriness and grain density of this material have shown promising results. If consistency in the processed waste is demonstrated, the material will be evaluated as a component in high-alumina refractory products.

Substitutes for Chromium in Alloy Steels

M. L. Glenn, Principal Investigator
Albany Research Center, Albany, Oreg.

Chromium is generally acknowledged to be one of the most critical of all strategic materials. Its importance in metallurgy is derived from its ability to impart properties to alloys for applications where resistance to oxidation, corrosion, wear, and high-temperature creep is essential.

The mining and minerals industries are dependent upon chromium alloys for many such applications including heavy machinery, retorts,



Computer designed chromium-free alloys for constructional steel.

and furnace parts. These applications are being reviewed, and research is underway to develop new alloys that contain less chromium yet still afford the required properties.

Development of new alloys starts with an evaluation of a proposed composition based on material properties, projected availability of the components, and cost. For constructional alloy steels used in such applications as gears and drive shafts, a computer analysis (computer harmonizing and applications tailoring) is being conducted. This analysis and subsequent laboratory research has shown that the chromium in these steels (SAE 4100 and 8600 series) can be replaced by more abundant alloying elements, such as molybdenum, and still maintain equivalent hardenability. These constructional steels account for 10 pct of the chromium consumed in the United States.

Alloys are being developed that would substitute for stainless steels, which account for about 70 pct of our chromium requirements. These new alloys contain less than half as much chromium as type 304 (18 pct Cr) and type 310 (25 pct Cr). The 304 stainless steel substitute derives its oxidation resistance from a combination of aluminum and silicon additions. The 310 substitute uses aluminum

for oxidation resistance, but it also derives substantial high-temperature strength as well as sulfidation resistance from particles of nickel aluminide dispersed uniformly throughout its matrix.

An 8 pct chromium alloy, designed for use in mildly corrosive environments, is an example of an alloy being developed for a special application. This alloy will substitute for materials now being used that contain 18 pct or more chromium—alloys that are sometimes overdesigned for the application.

Vapor Phase Preparation of Titanium Alloy Powder

M. B. Shirts and H. Dolezal, Principal Investigators
Salt Lake City Research Center, Salt Lake City, Utah

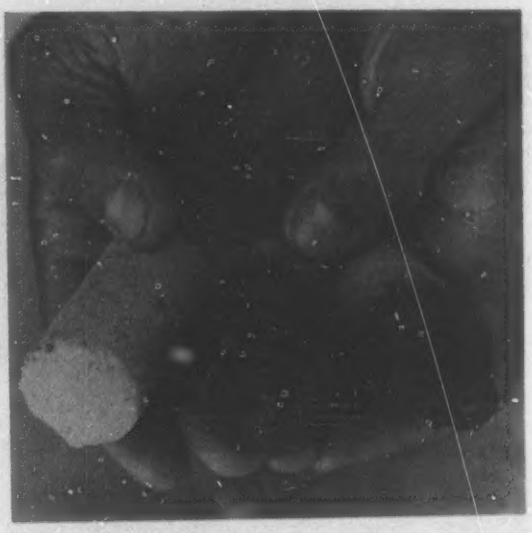
Titanium produced by the Kroll process yields a massive sponge type of material that is not easily reduced in size for blending. Metal produced by newer electrolytic methods forms soft dendritic crystals that are also difficult to reduce in size. Alloying elements are roughly blended with these coarse forms of titanium and pressed into consumable electrodes for melting. However, in order to achieve a uniform blend, the resulting ingot may have to be cut up, reblended, and remelted several times.

Research is being conducted on the development of methods for simultaneously reducing halides of titanium and alloying elements to yield a powder of the alloy or a homogeneous mixture of titanium and the alloying elements. Elimination of intermediate processing steps would reduce energy requirements and the powder could be used for the fabrication of powder metallurgy products and as a feed for production of ingots by the Bureau-developed inductoslag melting technique.

Refractories for Severe Service Conditions

Hendrik Heystek and T. A. Clancy, Principal Investigators
Tuscaloosa Research Center, Tuscaloosa, Ala.

Many high-temperature processes expose refractories to attack by high-alkali vapors or slags. Such conditions can occur in blast furnaces, glass furnaces, petrochemical reactors, coal gasification units, and incinerators. The alkali compounds may originate in either the raw materials processed or the fuel used. Failure of a mullite lining, an alumina refractory containing about 70 pct alumina, in a pilot plant research effort sponsored by the Department of Energy (DOE) was attributed to attack by alkali vapors. Subsequently, DOE entered into an agreement with the Bureau of Mines to evaluate commercial refractories under simulated gasifier conditions.



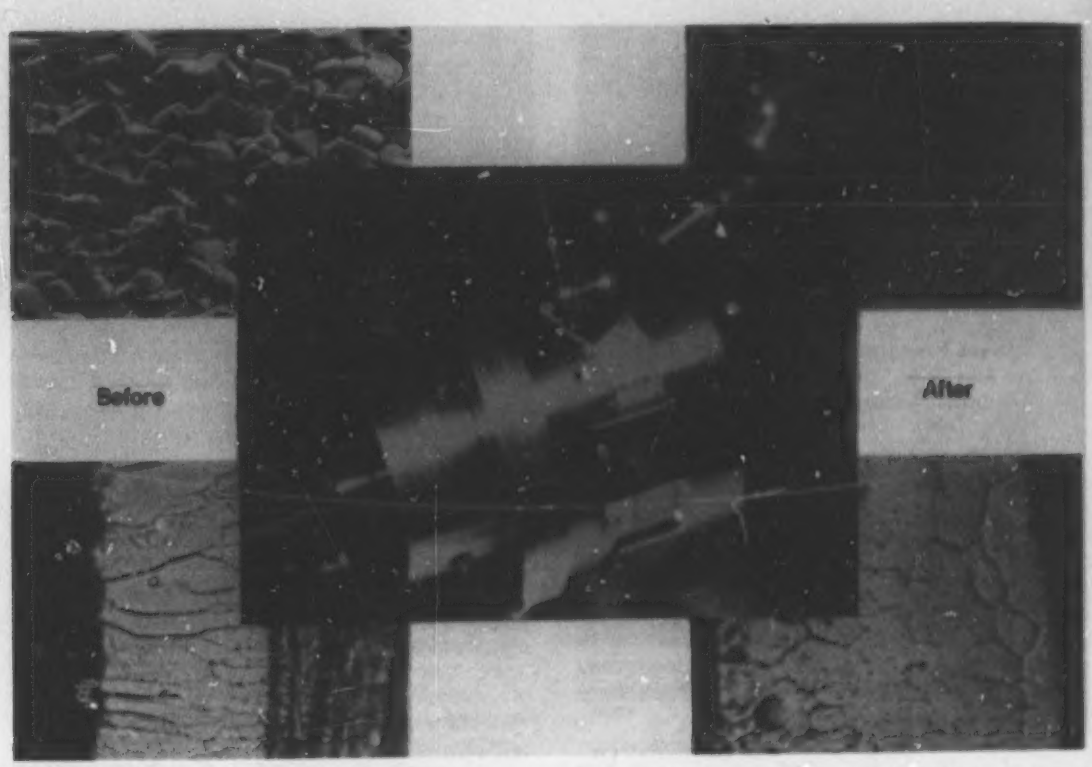
At high temperatures and pressures, gaseous environments containing alkalis aggressively attack some refractories. The reacted test sample on the right contains 70 pct alumina whereas the sample in the middle contains 45 pct alumina; the sample on the left is unreacted.

Research has revealed that large volume expansions occurred in refractories containing over 70 pct alumina. Analysis of the refractories indicated that the reaction of sodium vapor with the refractory at 1,000° C resulted in the formation of a mineral phase, carnegeite, that involved a large volume expansion and subsequent cracking. The studies also revealed that refractories containing 45 to 50 pct alumina did not crack and furthermore, phases that could cause cracking were not identified. These results indicate that at the temperature and alkali environment of slagging gasifiers, intermediate-alumina refractories should perform better than the more costly high-grade alumina refractories.

Basic and Applied Corrosion Studies

David R. Flinn, Stephen D. Cramer, and Bruce D. Sartwell, Principal Investigators
Avondale Research Center, Avondale, Md.

The cost of corrosion to the Nation each year is estimated to be upwards of $50 billion. Bureau scientists are engaged in a coordinated corrosion abatement program involving both fundamental and applied research. The objectives of the



Evaluation of laser surface melting for the consolidation of platinum coatings to eliminate porosity, and thereby enhance corrosion and oxidation protection.

fundamental work are to understand the many complex processes occurring at the material-environment interface and to determine the effects of material composition and structure on corrosion behavior.

Important material-environment interactions currently being studied include the formation of hydrogen on the surface of materials in aqueous environments, the effects of chloride ions and oxygen on the corrosion of stainless steels in acid solutions, and the effects of atmospheric pollutants on metal surfaces. Passivity of metals and alloys in aqueous environments is being investigated by determining the effects of oxygen on the composition and structure of corrosion films and by determining the stability of these films as a function of potential, time, and chloride ion concentration. The effects of aggressive atmospheric pollutants such as sulfur and nitrogen oxides and the constituents of acid precipitation on the corrosion of widely used structural materials is being investigated in a joint Bureau of Mines-Environmental Protection Agency study involving several sites on the east coast.

Fundamental studies are in progress also to correlate the chemical composition and structure of a material with corrosion resistance. New technologies are being employed to alter the composition and microstructure of only the near-surface region of a material, thus saving the time and expense of bulk alloy fabrication for laboratory studies. These technologies include ion implantation, which is capable of producing near-surface solid solution alloys of virtually any combination of elements; laser processing, which can intermix a thin coating with a substrate to produce a metastable solid-solution alloy structure; and sputter deposition to produce coatings of amorphous films. Since many of the alloying elements used in these studies are available domestically, substitutes for critical minerals presently used in alloys may be identified.

Applied studies are in progress to determine

suitable construction materials for use in chemical processing environments related to the treatment of ores. For example, pressure hydrometallurgy, designed to extract mineral and metal values from ores, involves highly corrosive and erosive conditions that greatly accelerate the degradation of structural materials which increases the potential hazard from materials failures. Localized corrosion is a significant problem and may be the principal cause of failure for structural materials in these environments.

Specific studies are being conducted to determine the susceptibility of Fe-Cr, Fe-Cr-Mo, and Fe-Cr-Mo-Ni alloys to localized corrosion and to develop suitable corrosion control procedures for operating temperatures of up to 250° C.

Rapid Identification of Scrap Metals

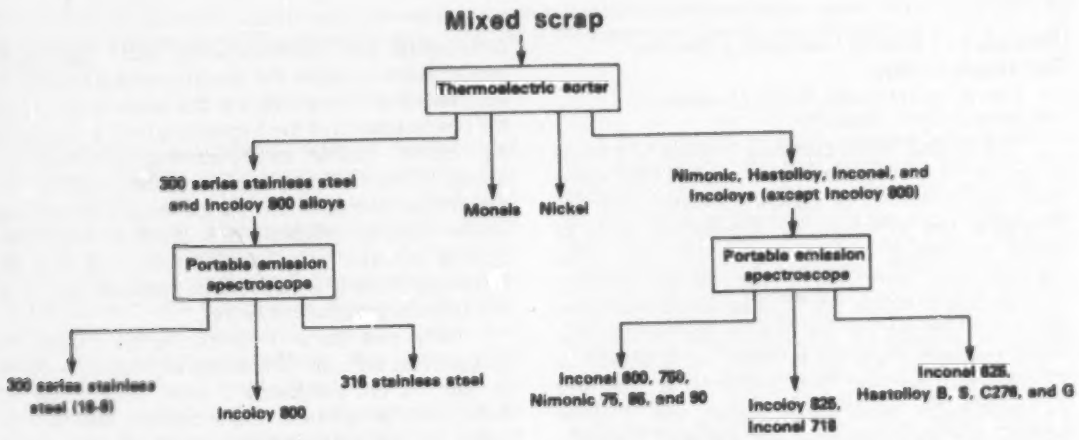
H. V. Makar, D. M. Soboroff, and R. D. Brown, Principal Investigators
Avondale Research Center, Avondale, Md.

The National Association of Recycling Industries (NARI) and the Institute of Scrap Iron and Steel (ISIS), as well as individual scrap processors, have indicated that many alloy groups require new or improved identification and sorting techniques. For example, more the 50,000 tons per year of cast heat- and corrosion-resistant alloys are downgraded to stainless and low-alloy steels. More than 120,000 tons per year of stainless steels are not effectively recycled. Effective recycling is of vital concern to the United States because of both the strategic and critical element content of many alloy groups and potential energy savings.

To alleviate this problem, the Bureau has been conducting research to (1) determine areas requiring new or improved sorting technology, (2) evaluate and develop new and improved identification and sorting methods, (3) test problem alloy groups, such as nickel- and cobalt-base alloys, to determine the most promising rapid identification methods, and (4) track trends in new alloy development in order to better predict their impact on scrap recycling.

A comprehensive survey of the methods used for identifying scrap metals has been made. Current methods which have been reviewed and evaluated include object recognition; density determination; magnet, spark, and chemical spot testing; thermoelectric and eddy current measurements; and various analytical techniques. Well-established methodologies used for applications other than metals identification, for example, colorimetry, ultrasonic and acoustic emission methods, magnetic permeability and susceptibility, infrared emission, and galvanic measurement have been considered in terms of their potential application.

In addition, a flowsheet for separating nickel-base alloys and stainless steels has been designed. This flowsheet, which uses thermoelectric response and optical emission spectroscopy, contains less than one-half the operations present in a conventional separation scheme based on chemical spot tests. Future plans call for testing this flowsheet in an operating scrap yard.


Mixed scrap
Thermoelectric sorter
300 series stainless steel and Incoloy 900 alloys
Monels
Nickel
Nimonic, Hastelloy, Inconel, and Incoloys (except Incoloy 900)
Portable emission spectroscope
Portable emission spectroscope
300 series stainless steel (18-8)
Incoloy 800
316 stainless steel
Inconel 600, 750, Nimonic 75, 85, and 90
Incoloy 825, Inconel 718
Inconel 625, Hastelloy B, S, C276, and G

A flowsheet based on chemical spot tests has been designed for testing. The flowsheet contains less than one-half the operations present in a conventional separation sheme.

Thermoelectric response can be used in alloy identification. The calculator is programed to convert the instrument reading into an alloy classification.

Utilization of Wastes Containing Zinc for Electrogalvanizing

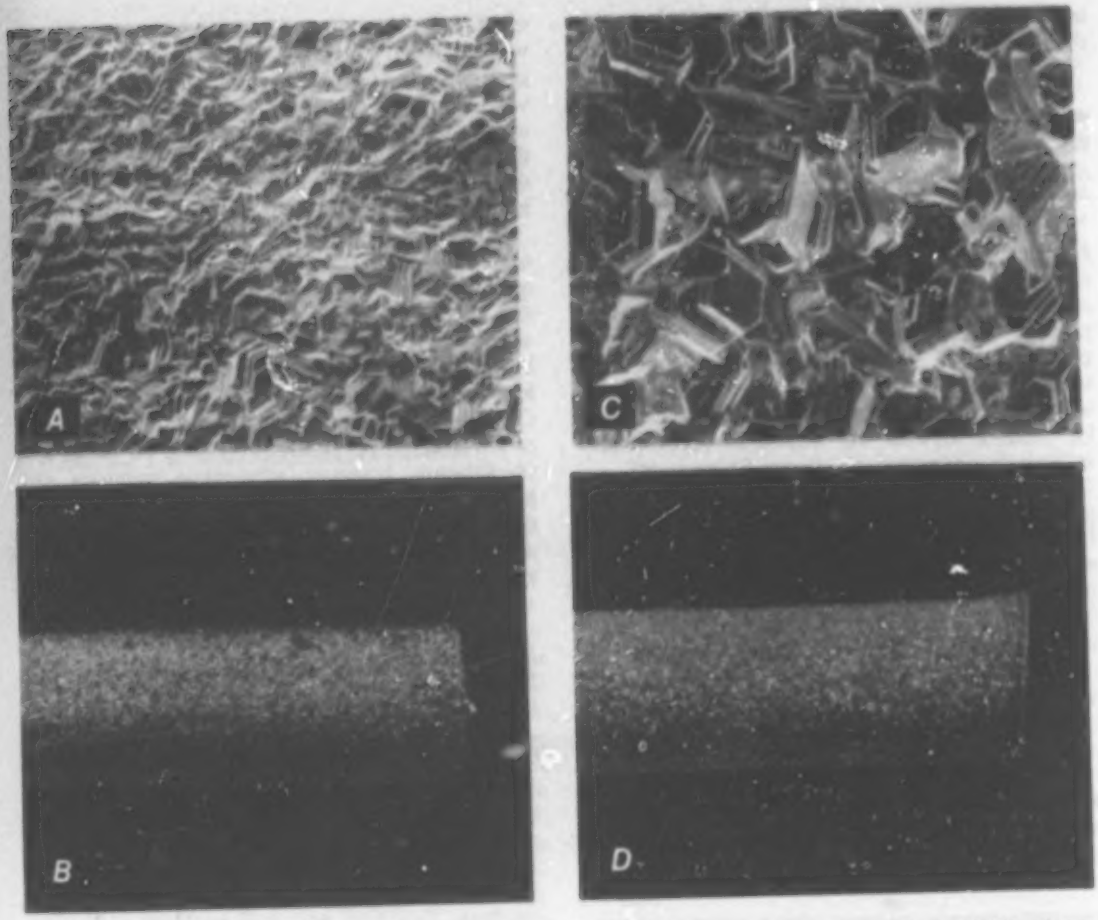
E. R. Cole, Jr., and M. Dattilo, Principal Investigators
Rolla Research Center, Rolla, Mo.

The United States currently imports two-thirds of the zinc consumed each year, while at the same time large quantities of wastes containing zinc are generated and subsequently disposed of. A list of wastes generating operations includes steel mills, brass smelters, secondary copper smelters, radiator manufacturing plants, etc. Conservative estimates place the amount of zinc potentially recoverable from domestic stack dusts alone at 200,000 to 235,000 tons per year. Not only is the zinc, as well as considerable other metal values, lost in these wastes, but increasingly more stringent Government regulations are making disposal costly.

The use of some of these wastes as feed to a commercial zinc electrowinning plant has been unsuccessful because the electrowinning process is very sensitive to impurities in the waste even when the concentration of the impurity is only a few parts per billion. Unlike electrowinning, electrogalvanizing, a method for applying zinc coatings by electrolysis, is a potential use for these zinc-bearing wastes because relatively high levels of impurities can be tolerated. The current source of zinc for electrogalvanizing is high-purity cathode zinc that has undergone electrowinning.

Work was started recently by the Bureau in conjunction with the University of Missouri—Rolla as part of an integrated 3-year, joint effort to determine the technical and economic feasibility of using zinc-bearing wastes instead of high-purity metal as the source of zinc for electrogalvanizing.

Quantities of zinc-bearing wastes have been



Structure of wire electrogalvanized in both waste and pure solutions at ambient temperature using a current density of 200 milliamps per square centimeter. A and B, waste solution at × 1,000 and × 10, respectively; C and D, pure solution at × 1,000 and × 10, respectively.

obtained from four different sources (waste water treatment sludge, secondary copper smelter flue dusts, electric arc furnace flue dusts, and lead smelter flue dusts). These wastes are leached with sulfuric acid to extract the zinc for electrogalvanizing. The resulting zinc sulfate solutions, both as extracted and after different degrees of purification, have been used to electrogalvanize 1070 alloy steel wire. After electrogalvanizing, the wires were subjected to bend and drawing tests and to accelerated corrosion tests in a salt spray cabinet. In each case the wires electrogalvanized in solutions extracted from the wastes were compared with wires electrogalvanized in "pure" solutions under identical plating conditions.

Early results of these tests are very encouraging. Indications are that some of the impurities present in the zinc sulfate solutions derived from the wastes enhance the quality of the electrogalvanized zinc coatings. The following example is typical. Specimens plated in solutions containing cadmium, from a few parts per million up to several hundred part per million, maintained a coherent surface after drawing and required the least amount of drawing energy. Also, zinc deposits made from solutions containing 75 ppm cobalt and 50 ppm nickel resembled deposits made from pure solutions except that the zinc platelets were smaller. The best corrosion resistance obtained to date has been from specimens electrogalvanized in an electrolyte con-

taining 500 ppm cadmium, 36 ppm cobalt, and 8 ppm nickel.

Byproduct Mineral Recovery From Phosphate Wastes

A. R. Rule and J. H. Russell, Principal Investigators
Albany Research Center, Albany, Oreg.

When Western U. S. phosphate ores are processed to produce agricultural fertilizer and elemental phosphorus for chemical products, large amounts of wastes are generated. During this processing certain trace elements contained in the phosphate ores, such as vanadium, uranium, zinc, silver, and gallium, tend to concentrate in the waste. Because of this concentrating effect, it may be possible to treat the wastes to economically recover these resources as byproducts.

In industrial operations a washing and sizing process is used to separate the phosphate minerals from the fine waste (tailings) in the ores. Because the vanadium minerals are extremely fine in size, they tend to concentrate in the tailings. If the vanadium contained in these tailings were recovered, it could supply about 80 pct of our annual domestic needs. In addition to the vanadium values, about 20 pct of the phosphorus and uranium in the original ore is left in the tailings and are potentially recoverable also.

An acid leaching approach has been examined as a method for recovering these byproducts from tailings. With this technique, phosphate tailings, thickened to 50 pct solids, are slurried with sulfuric acid and heated to a constant boiling temperature of 110° C. After about 30 min the slurry is diluted with water to complete extraction of vanadium, phosphorus, and uranium. About 90 pct of the vanadium and phosphorus and over half of the uranium in the tailings have been extracted with this technique. Research now is being carried out to determine the potential for adapting this approach to an industrial process.

Valuable byproducts are contained in phosphate processing wastes. Research is being conducted to recover zinc, silver, and gallium from flue dust and uranium and vanadium from mill tailings.

In the electric furnace processing of phosphate ores, elemental phosphorus is vaporized. The dusts separated from the phosphorus vapor contain significant concentrations of zinc, silver, and gallium as well as some residual phosphorus. Studies are being conducted to devise an economical process for recovering these values from the dusts. Caustic-cyanide leaching will recover up to 90 pct of the zinc, 70 pct of the silver, and 80 pct of the phosphorus, however, alternative methods are being investigated to find a means for extracting these valuable minerals which will not present the disposal problems associated with the use of cyanide.

Metal Recovery From Secondary Copper Smelter Flue Dusts

H. V. Makar, D. M. Soboroff, and F. J. Palumbo, Principal Investigators
Avondale Research Center, Avondale, Md.

Current estimates place the zinc content of copper and brass secondary smelter flue dusts produced annually at approximately 40,000 to 120,000 tons, with a significant percentage of the flue dust being produced by relatively small smelters. This high-zinc dust problem represents one of the most pressing recycling challenges today. At the present time, most of the dust is disposed of in landfills with a small amount recycled by agriculture, paint, and other industries. Owing to the character of the dusts, it is anticipated that they will be classified as hazardous wastes, resulting in increased costs for disposal. The dusts generally contain 20 to 60 pct zinc, 0.1 to 3 pct tin, 8 to 20 pct lead, and 1 to 6 pct copper; therefore, use of the dusts for landfilling without recycling represents a significant loss of important metal values.

To address this problem the Bureau of Mines has directed its research efforts toward developing low-cost technology to produce recyclable and/or salable products from these dusts. Bench-scale testing has shown alkaline leaching to be a promising approach.

A 50-lb/hr (pound per hour) unit has been designed and constructed. This unit combines a

two-stage alkaline (NH_4Cl-NH_4OH) leach, a cementation circuit, and a crystallization tank with appropriate liquid-solid separation stages to produce a copper-lead-tin residue, a cement copper-lead product, and zinc oxide. Both the residue and the copper-lead product are immediately recyclable by the smelter. Markets being investigated for the zinc oxide product include the rubber, chemical, agriculture, and pharmaceutical industries. Tests using dusts from major secondary processors are underway to better define economics and technical parameters.

Rare Earth-Cobalt Permanent Magnets

E. Morrice and J. W. Walkiewicz, Principal Investigators
Reno Research Center, Reno, Nev.

Samarium-cobalt (Sm-Co) alloys possess energy products (BXH) and coercivities higher than any commercial permanent magnet material is use. During the past 5 years many new and successful applications of Sm-Co magnets, such as microphones, headphones, and magnetrons for microwave ovens, have been created. Because of the exceptional physical and magnetic stability of Sm-Co, magnetically suspended gyrocontrol systems for satellites and space vehicles are being developed. Electrical devices of lower weight and size with improved performance are possible because of the high magnetic energy available with Sm-Co. This weight decrease is especially attractive to the automotive industry. Starter motors, alternators and generators, and auxiliary motors employing Sm-Co magnets offer a considerable energy savings.

Widespread application of Sm-Co magnets is limited by the availability of samarium and cobalt. The supply of samarium is much less than the rare-earth elements lanthanum (La), neodymium (Nd), and praseodymium (Pr). For example, in a principal source of rare earths, the mineral bastnasite, the lanthanum content is 15 times more than the samarium content. A great disparity between domestic production and consumption of cobalt also exists and could become a serious problem in a national emergency.

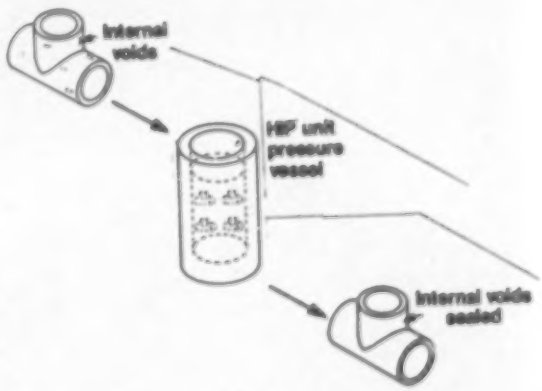
The Bureau has helped to alleviate the samarium and cobalt availability problem by developing a samarium-free, rare earth-cobalt magnet using mischmetal prepared from naturally occurring rare-earth compounds. By substituting copper and magnesium for part of the cobalt, coercivities approaching those of Sm-Co magnets were obtained. Additional substitution of cobalt by iron resulted in an improved energy product and a 17 pct decrease in the cobalt requirement. By adjusting the composition of the rare-earth components found in natural mischmetal to produce a synthetic mischmetal (M: 20 pct La, 60 Pr, and 20 Nd), an energy product was obtained that is comparable to Sm-Co. The research demonstrated the potential for tailoring selected properties of rare earth-cobalt magnets so that samarium and cobalt can be conserved.

Improved Titanium Components Through Innovative Processing Technology

P. E. Cites, Principal Investigator
Albany Research Center, Albany, Oreg.

Titanium became an important industrial material during the 1950's as a result of pioneering work by the Bureau of Mines. Since that time there has been progress in all stages of development of this metal and its alloys, but because of its high cost, its use has been limited to aircraft components and to special pumps and valves in the chemical industry. Lowering the cost of titanium components would increase the use of this abundant material in a variety of applications, particularly as a substitute for such critical and strategic materials as cobalt and chromium.

One of the methods being studied to reduce the cost of titanium parts is the use of castings prepared by a low-cost, sand-molding technique developed by the Bureau. The use of castings instead of machining components from heavy



Hot isostatic pressing (HIPing) can be used to heal internal defects in castings. Voids as large as 0.5 inch in diameter can be healed using a combination of high temperature and high pressure, provided sufficient material is available to completely fill the void.

forgings not only would save the cost of machining, but also would reduce the amount of metal lost to scrap. Some finished parts weigh only one-twentieth of the weight of the forging from which they are machined. Unfortunately, castings are not as strong as forged material because of internal voids or defects caused by shrinkage of the metal during solidification. In some cases, these defects can be healed by a process called HIPing (hot isostatic pressing).

HIPing consists of subjecting castings to a combination of high pressure (15,000 psi argon) and high temperature (900° C). At this temperature and pressure the metal in the casting deforms sufficiently for any voids in the metal to be closed, and subsequent bonding of the closed surfaces completely heals the defect so that its properties approach those of forged material.

Current work is being directed to the adoption of the HIPing technique to parts made by casting titanium alloys in sand molds. Data obtained from this research will provide information on how less expensive castings could be used to conserve material while reducing the cost of preparing titanium shapes.

Foundry Charge Materials Chemistry

R. H. Nafziger and R. F. Farrell, Principal Investigator
Albany Research Center, Albany, Oreg.

During the past decade, over 80 pct of all domestic iron castings were produced from re-

Analyses of a portion of one group of cast iron samples from a variety of domestic foundries. The samples were provided by participating foundries to the American Foundrymen's Society, which submitted them to the Bureau for analyses. Of particular importance is the delineation of the effect of charge materials and other variables used on the quality of ferrous castings.

melted scrap iron and steel. The scrap was derived from such diverse sources as automobiles, pipe, tubing, wire, aircraft, and mechanical equipment. During this same period, raw alloy steel production has increased to meet the demands of greater strength or hardness. With the increase in alloy steel production, greater amounts of alloying constituents could enter the scrap metal cycle as scrap is recycled repeatedly. If used as foundry charge materials, scrap containing detrimental elements such as aluminum, antimony, boron, bismuth, chromium, lead, molybdenum, phosphorus, and sulfur could severely degrade the quality of iron castings and result in wasteful rejects.

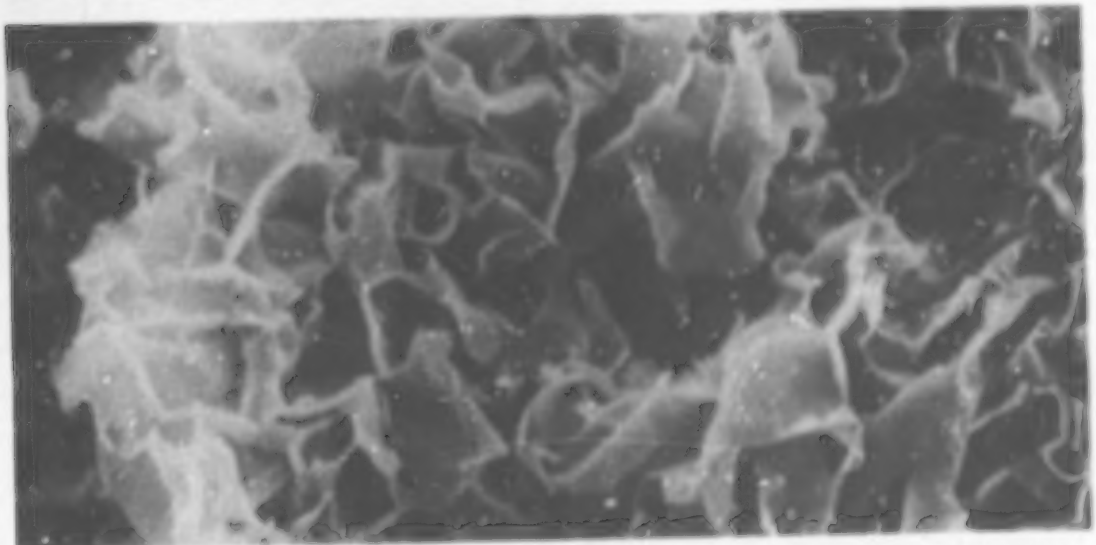
Reliable information is not available on the precise amount of tramp elements contained in ferrous castings made over a significant period of time. To supply this needed information, the Bureau is cooperating with the American Foundrymen's Society by analyzing samples of approximately 56 gray, ductile, and malleable iron castings from approximately 40 foundries throughout the United States. Determinations are being made for the level of 28 tramp elements in samples that are submitted quarterly. Comparisons of the analytical data as a function of charge materials, furnaces, and foundry locations over a period of time should delineate progressive changes in the quality of castings. Results will provide the domestic foundry industry with necessary information to take corrective action, if warranted, in time to avert costly waste.

Fundamentals of Flocculation

B. J. Scheiner and D. A. Stanley, Principal Investigators
Tuscaloosa Research Center, Tuscaloosa, Ala.

Basic research is being conducted to determine how organic polymers flocculate fine particles produced during the processing of minerals. An understanding of the flocculation mechanism has been obtained through studies employing viscometry and ion-exchange techniques. A mathematical expression describing the relationship between flocculant requirement and the hydrated radius to charge ratio of the cations on the surface of clay particles has been developed. The equation is expressed as $y = (ax + b)^2$ where a and b are constants, y is the flocculant requirement, and x is the hydrated radius to charge ratio.

Based upon the understanding obtained from these fundamental studies, new organic polymers have been designed and are being synthesized. In addition, the equation now is being used to develop a technique to selectively recover mineral values contained in mineral waste products. Initial emphasis of the selective flocculation research is being focussed on developing a technique to recover phosphate values from phosphate clay wastes.



The scanning photomicrograph (× 10,000) shows the cellular structure that is common to lithium montmorillonite clay slurries. Because of the structure, dewatering by conventional flocculation processes is difficult. Research on the use of polyelectrolytes in combination with flocculants to alter the structure, thus making dewatering possible, is underway.

Mineral Data Analysis

Mineral data analyses were conducted at the Washington, D.C., headquarters, and field operations centers in:

Denver, Colo.,

Juneau, Alaska,

Pittsburgh, Pa.,

and Spokane, Wash.

best copy available

READEX FICHE

Field Assessment and Evaluation

Mineral Resource Evaluation of Wilderness Lands

L. Gibbs, R. Pavlovich, T. Frieders, and B. Goodwin, Principal Investigators
Field Assessment and Evaluation Staff, Washington, D.C.

The Wilderness Act of 1964 requires the Bureau of Mines and the U.S. Geological Survey to conduct mineral assessments of national forest lands placed in the National Wilderness Preservation System. The act designated 9.3 million acres as wilderness and directed reviews of an additional 5.5 million acres of primitive areas. At present, there are 25.1 million acres of forest lands designated wilderness by Congress. The goal is to complete the assessments before January 1, 1984, after which mineral exploration will be forbidden in these areas. The law also states that the mineral values are to be reevaluated periodically.

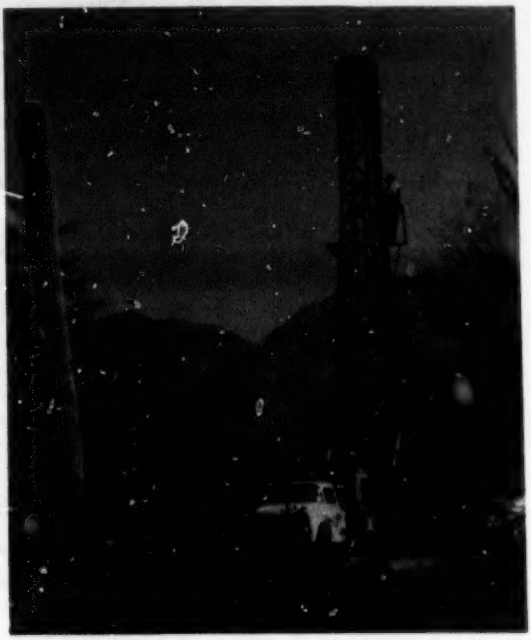
Since 1970 the Forest Service, the Department of the Interior, and the Congress have identified additional acreage as candidates for inclusion in the wilderness system. By the end of 1981, mineral surveys had been completed on about 18 million acres of wilderness and wilderness candidate areas. About 15 million acres of forest lands remain to be studied. At the current rate of appraisal, studies of the remaining areas should meet the legislative deadlines. Results of Bureau studies are being released in a series of mineral land assessment (MLA) open file reports; over 130 have been released to date.

The Federal Land Policy and Management Act

Mineral resource evaluation of wilderness lands.

of 1976 directs the Bureau of Mines and the U.S. Geological Survey to conduct mineral surveys on potential wilderness areas administered by the Bureau of Land Management (BLM) before the Secretary of the Interior makes recommendations to the President. To date 34 studies of BLM lands covering 2.4 million acres have been completed; in 1982, work began or continued on an additional 1.34 million acres. It is estimated that 6.6 to 11.3 million acres of BLM public lands will require mineral surveys.

Joint reports on the mineral potential of recently assessed areas are now published as U.S. Geological Survey Miscellaneous Field Studies Maps and are used in deciding wilderness suitability by the managing Federal agencies and the Congress and for general information by a broad range of users including the mining industry. Site-specific project information is being maintained on the Bureau's Automated Minerals Information System, an integrated data base system that supports the mineral information collection and analysis activities. This system improves project tracking by providing easy accessing, updating, and sorting capabilities, and it allows rapid preparation of project status reports.



Subsurface deposit delineation on Indian lands in Arizona.

Mineral Resource Evaluation of Tribal Lands

R. Pavlovich, Principal Investigator
Field Assessment and Evaluation Staff, Washington, D.C.

The Bureau of Mines and the U.S. Geological Survey are evaluating the mineral and energy resources of Indian-owned lands under a Bureau of Indian Affairs program designed to assist the Indian people in achieving their goal of self-determination. The Indian land appraisal program, conducted on 265 reservations, informs the tribes about the existence of mineral and energy resources on their lands and describes the potential for further development. This information aids the Indian tribes in making decisions about their mineral resources.

Evaluation of mineral energy resources on Indian lands is conducted in three phases. In phase I the Bureau and the Geological Survey compile and summarize available information on the geology and mineral resources of individual Indian reservations. Phase II fieldwork, if justified, may consist of sampling, trenching, and limited exploration drilling by the Bureau to better define particular minerals. If the phase II findings indicate a need for further refinement, then more intensive exploration is conducted in site-specific areas under phase III. The phase III studies usually consist of exploratory drilling to determine the quantity, grade, and possibly the marketability of the particular minerals under investigation. A written tribal resolution permitting work on the reservation must precede any phase II or III study.

During fiscal year (FY) 1982, 8 additional phase I studies were completed for a total of 103; and 3 additional phase II studies were completed for a total of 15. The Bureau started six new phase III studies in FY 1982 which, together with two ongoing studies, will carry over into FY 1983. To date, the Bureau has completed three phase III studies.

Reports on the mineral appraisal of Indian lands are regarded as proprietary. Inquiries about these studies should be directed to the appropriate tribal authority.

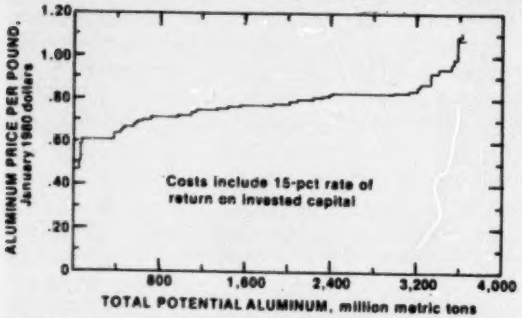
Aluminum Availability—Market Economy Countries: A Minerals Availability System Appraisal

G. R. Peterson and S. J. Arbelbide, Principal Investigators
Minerals Availability Field Office, Colo.

To determine the availability of aluminum from world bauxite resources, the Bureau investigated 139 bauxite deposits worldwide and evaluated the potential production of aluminum based on the demonstrated resources of bauxite ore from 91 mines and deposits in 22 market economy countries.

The demonstrated resources of the bauxite mines and deposits included in this study represent an in situ resource of 20.2 billion tons of bauxite. Total identified bauxite resources in market economy countries amount to roughly 31.9 billion tons. Of the demonstrated resource, some 18.8 billion tons of bauxite considered minable provides a production potential of 3.6 billion tons of primary aluminum. Based on the assumptions in this study, the analysis indicates that at an aluminum price of $0.75 per pound (in January 1980 dollars), about 1.3 billion tons of aluminum is potentially available; at $0.85 per pound, almost 3 billion tons would be available; and at $1.13, all 3.6 billion tons of aluminum would be available. The U.S. producer price for aluminum in January 1980 was $0.66 per pound. On an annual basis, with a $0.75 aluminum price, approximately 17 million tons of aluminum could be potentially available in 1985, and over 19 million tons could be available in 1990.

Given the wide geographic distribution of bauxite deposits, stable supplies of bauxite for aluminum production seem assured well into the next century. However, a tight-market situation could develop during the 1990's unless the real price of aluminum increases enough to stimulate massive new investments in production capacity, particularly in refining and smelting. This study indicates that a real price of at least $0.85 per pound would be required to stimulate the required investments and provide a sufficient rate of return on invested capital.



Total potential aluminum production from bauxite resources in market economy countries.

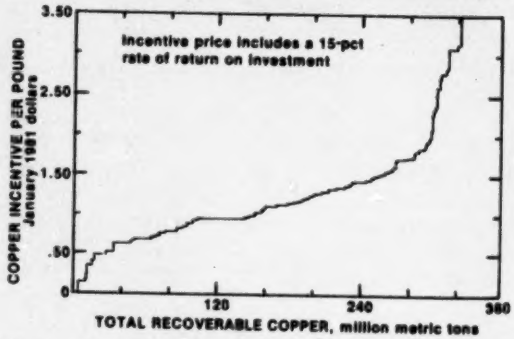
Copper Availability—Market Economy Countries: A Minerals Availability System Appraisal

R. D. Rosenkranz, E. H. Boyle, Jr., and K. E. Porter, Principal Investigators
Minerals Availability Field Office, Denver, Colo.

The Bureau has investigated the availability of copper from known deposits in market economy countries. Two-hundred seventy-one deposits were found to have demonstrated resources totaling 406 million tons of contained copper, 80 pct of which is recoverable using existing technology. Detailed geologic, engineering, and economic evaluations were performed to determine each deposit's potential for copper production.

At the January 1981 copper market price of $0.87 per pound, an estimated 135 million tons of copper can be economically produced, primarily from mines operating at the time of the study. At this same price, market economy country mines were capable of economically producing only 4.2 million tons of refined copper per year, much less than the 1981 production of 6.2 million tons. This indicates that many mines operated at a loss in anticipation that market conditions would improve.

The estimated cost of production, including profit, for U.S. mines producing (or temporarily shut down) at the time of the study was $0.98 per pound of copper, $0.20 higher than the average cost of other market economy producing mines. At the January 1981 copper market price of $0.87 per



Total copper availability from market economy country mines and deposits.

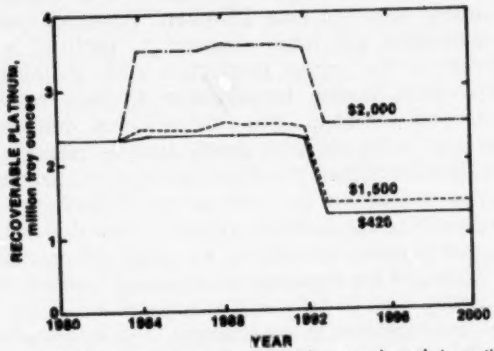
pound, only 8 of the 36 producing U.S. mines were able to operate at a profit. Analyses also indicate that the profitability of world mines is highly sensitive to changes in operating costs and byproduct prices.

Platinum Availability—Market Economy Countries: A Minerals Availability System Appraisal

T. F. Anstett, D. I. Bleiwas, and C. Sheng-Fogg, Principal Investigators
Minerals Availability Field Office, Denver, Colo.

The Bureau of Mines investigated the availability of platinum from known major deposits in market economy countries. Fifteen of these deposits contain demonstrated resources totaling 302 million troy ounces of platinum. Detailed geologic, engineering, and cost evaluations were performed on each of the deposits to determine its potential for platinum production. There are large amounts of demonstrated platinum potentially available from market economy deposits that were not analyzed owing to lack of adequate data or to technological limitations. These include 297 million troy ounces contained in the UG2 and Platreef horizons of the Bushveld Complex, South Africa.

This Minerals Availability System appraisal indicates that about 110 million troy ounces (2.3 million ounces annually) of platinum are potentially available at the January 1980 producer price of $420 per troy ounce, nearly all from South Africa. An additional 85 million troy ounces occurring in Zimbabwean deposits would become available only through more than a quadrupling of that price. In order to meet the projected world demand of 3.5 million troy ounces in 1990, the platinum price may have to increase. Only one domestic deposit, the Salmon River in Alaska, is capable of producing platinum at $420 per troy ounce. Regardless of price, at assumed production capacities, domestic deposits could supply less than 10 pct of annual U.S. requirements.

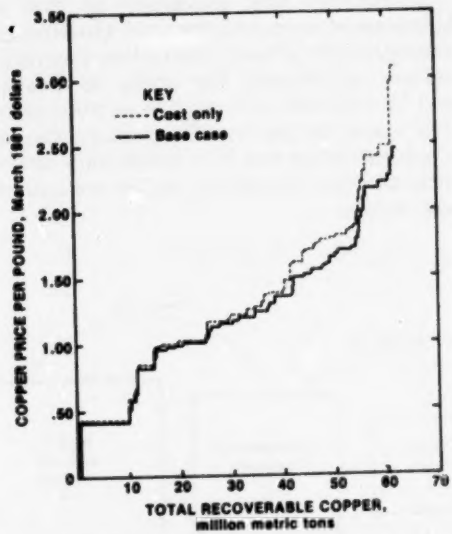


Annual platinum potentially available at selected incentive prices. Costs are in January 1980 dollars. Incentive price includes a 15-pct rate of return on investments.

The Depletion Allowance and Domestic Minerals Availability—A Case Study in Copper

Paul R. Thomas, Robert L. Davidoff, and Melinda M. Quinn, Principal Investigators
Minerals Availability Field Office, Denver, Colo.

The Bureau evaluated the impact of the depletion allowance upon the economic availability of copper from domestic deposits. The potential long-run percentage depletion deduction, cumulated over the life of the properties, was estimated at approximately $2.5 billion for producing properties and up to $11.7 billion for nonproducers. The income transfer, in the form of higher Federal income tax payments if the allowance were repealed, was estimated at $1.5 billion for producing properties and up to $8 billion for nonproducers. The percentage depletion allowance, through its role in determining Federal income tax liability, was found to be very significant in affecting profitability. Repeal of the allowance could result in major domestic copper availability reductions at all price levels, now and in the future, as a result of reduced profit margins for current producers, and



Potential total copper production at various prices from selected producing and nonproducing domestic copper properties, evaluated with the percentage depletion allowance (base case) and with an allowance for cost depletion only.

postponement of development decisions for nonproducers.

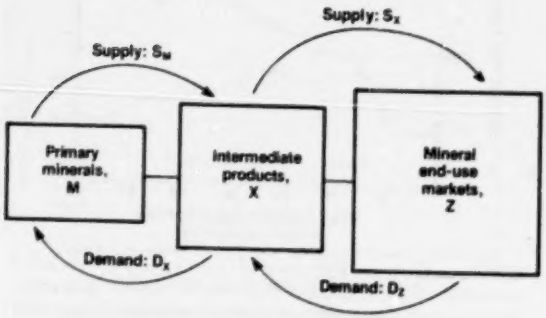
It was demonstrated that a 50-pct reduction in the percentage depletion rate applicable to copper would also result in a significant decrease in profitability for nonproducing properties. For producing properties, the percentage depletion rate on copper was shown to be less significant than the income limitation that is placed upon the total amount of the depletion deduction. Repeal of the minimum Federal tax provision was shown to be significant in enhancing profitability for both producing and nonproducing deposits. The study concludes that the percentage depletion allowance operates as an important method of capital recovery and production incentive.

Minerals Policy and Analysis

SIC-Based Demand Information System for Nonfuel Minerals

Kung-Lee Wang, Technical Project Officer
Branch of Economic Analysis, Washington, D.C.

This study describes and evaluates a new Standard Industrial Classification (SIC) based end-use data system for minerals that is designed to link the demand for minerals to economic activity in commercial uses. The new data system is two-dimensional. The first dimension of technical product classes (TPC's) measures the consumption of minerals in major primary intermediate products. The second dimension measures the consumption of these TPC's in SIC end-use sectors in sufficient detail to identify the major determinants of demand for each TPC. Intercommodity comparisons are achieved at the level of SIC two-digit major groups. The methodology was developed so that all available sources of information from Government and industry can be utilized. The system is expected to improve significantly the ability to forecast demand for minerals, and provide an information base that would, for the first time, permit resolution of such questions as trends in substitution among materials and the intensity of use of materials in end-use sectors.



Basic linkage in the supply and demand for minerals.

An Input-Output Analysis: The Impact of a Defense Buildup on the Mineral Industries

Kung-Lee Wang, Technical Project Officer
Branch of Economic Analysis, Washington, D.C.

The analysis utilizes a 470-sector input-output (I-O) table developed by the Bureau. There is a table for every fifth year between 1958 and 1977. A series of interactive computer programs has been developed which allows the I-O table to be used to assess the impact of changes in the mix of economic output on all segments of the economy. The computer program allows the user to aggregate the 470 sectors to any number desired. This particular study assesses the impact of a rapid defense buildup on the gross output of the economy, value added by sector, and personal income and employment by sector.

Technological Innovation in the Copper Industry

Louis J. Sousa, Technical Project Officer
Branch of Technical Analysis, Washington, D.C.

The opinion of technological experts in industry, Government, and academia is being systematically surveyed to develop a coherent and comprehensive assessment of the expected direction and extent of technological change in the copper industry over the next 25 years. Potential new technologies are being assessed in each of six phases of the copper production cycle including exploration, mining, beneficiation, smelting, refining, and recycling. The technological forecast provided in this study will enable analysts, planners, and decisionmakers in industry and Government to better understand the potential for technology to improve the competitive position of the domestic copper industry. In addition, the study will provide a ranking of the expected net economic benefits of adopting each of the major anticipated technological developments in the industry. The assessment methodology developed in the study is designed to assist minerals research and development managers in choosing the most promising avenues of research.

Minerals Information

Minerals information collection and evaluation activities were conducted at the Washington, D.C., headquarters.

Automated Minerals Information System

L. Michael Kaas, Chief
Division of Minerals Information Systems, Washington, D.C.

The Bureau has established 35 data bases, comprising a central data base that covers a widening spectrum of domestic and foreign minerals information, from ore reserves through end uses, in the Automated Minerals Information System (AMIS). Other information available includes Minerals Industry Location System (MILS) data, commodity survey respondent data, commodity price data, General Services Administration stockpile data, and U.S. consumption patterns for nonfuel mineral commodities from 1960 through 1981, along with selected economic indicators for these same years. AMIS is an online, interactive computer system with the capability of answering queries, producing statistical and analytical reports, and graphically displaying MILS data with country, State, and county boundaries.

Ongoing development of the AMIS makes use of current data communications, computer graphics, and data base technologies to allow for cross-referencing and integration of information from such various sources as domestic mineral production surveys, foreign mineral surveys, mineral deposit evaluations, public land appraisals, mineral research activities, the United Nations, the World Bank, and the U.S. Geological Survey. The AMIS is being developed in phases designed to meet the unique requirements of a variety of users.

Phase I provides a comprehensive base of minerals information to support the minerals analysis activities of the Bureau. Data on 34 of the most critical commodities will be available by 1983. Phase II will develop more effective commodity data subsystems to support the minerals data collection and dissemination activities of the Bureau. Phase II will expand AMIS data coverage to a more detailed level, increase the efficiency of commodity data processing, and provide improved support for analytic activities. The Phase II Copper Data Subsystem and the Respondent Control Data Subsystem have been established. Seven additional commodity data subsystems will become operative in 1983.

Minerals Data Source Directory

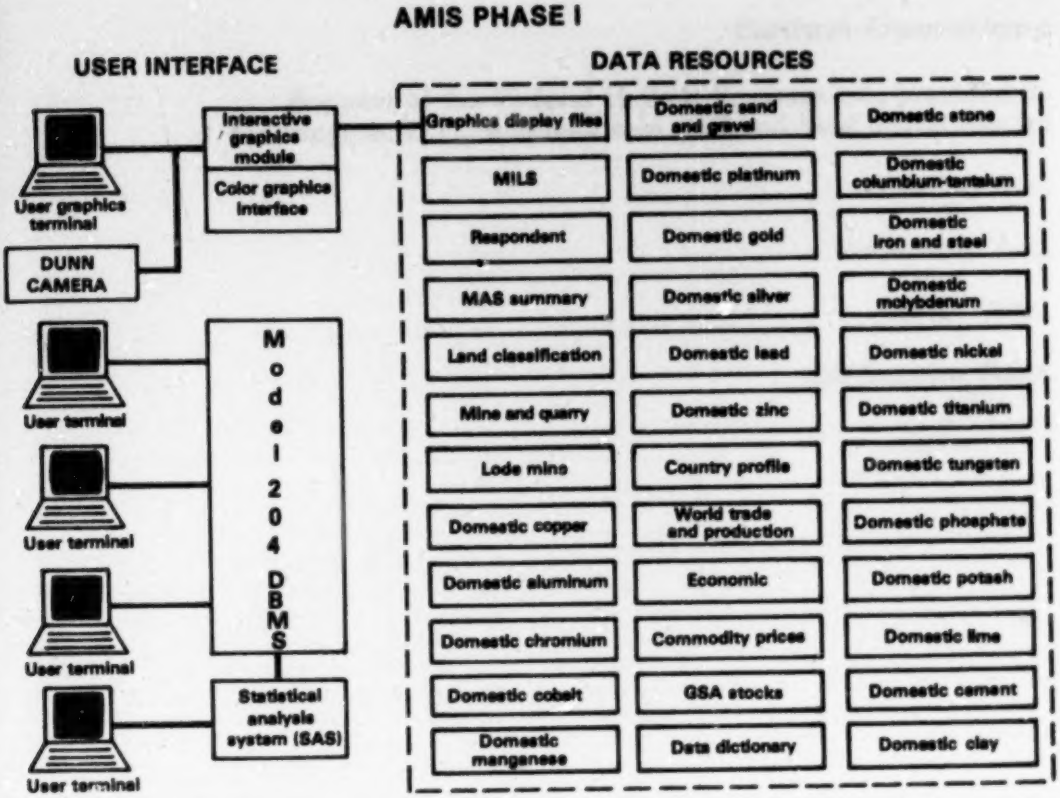
L. Michael Kaas, Chief
Division of Minerals Information Systems, Washington, D.C.

An interagency Minerals Information Coordinating Committee, chaired by the Bureau, has been established to identify and recommend solutions to Government minerals information issues. The Committee's Minerals Data Working Group is identifying data compatability problems and data gaps and is making recommendations for their solutions. A Minerals Data Source Directory has been compiled as a result of the effort.

Supply-Demand Projection for Steel Mill and Foundry Products

Frederick J. Schottman, Technical Project Officer
Division of Ferrous Metals, Washington, D.C.

A forecast of U.S. raw steel production capacity and the price of carbon steel through 1990 is being prepared. With assumptions on technology the study will project the capital requirements of the steel industry and requirements for scrap, iron ore, hot metal, and electricity. These forecasts will be based upon assumptions as to the level of imports and the level of activity in various steel consuming industries.



The AMIS User Interface will permit direct use of the AMIS without time-consuming and costly programing. Three categories of functions are currently provided to access the information in the AMIS Phase I Data Resources. These are inquiry functions, graphic display functions, and statistical functions.

Inquiry functions permit users to access, manipulate, and display data directly online through ad hoc user written inquiries or by the use of a library of predefined inquiries. The inquiry function is supported by a powerful, user-friendly language. Simple ad hoc inquiries are answered and complex reports are generated with the same user language.

The User Interface also provides the capability of displaying information in the Mineral Industry Location System (MILS) data base on maps showing county and State boundaries. These displays are easily developed on a user's graphic terminal through a menu selection process.

The Statistical Analysis System (SAS) and SAS/GRAPH provide all of the necessary tools for data analysis: information storage and retrieval, data modification and programing, report writing, statistical analysis, and file handling. Complete statistical analysis procedures are supported ranging from simple descriptive statistics to complex multivariate techniques. Complete business graphics are provided for the display of information. An easy-to-use interface to the AMIS data resources has been developed to allow the use of data in the AMIS with the SAS.

Helium Operations

Support of the Federal Helium Program was provided by Washington, D.C., headquarters staff and field operations in:

Amarillo, Tex.,

Masterson, Tex.,

Keyes, Okla.,

and Satanta, Kans.

Helium Activities

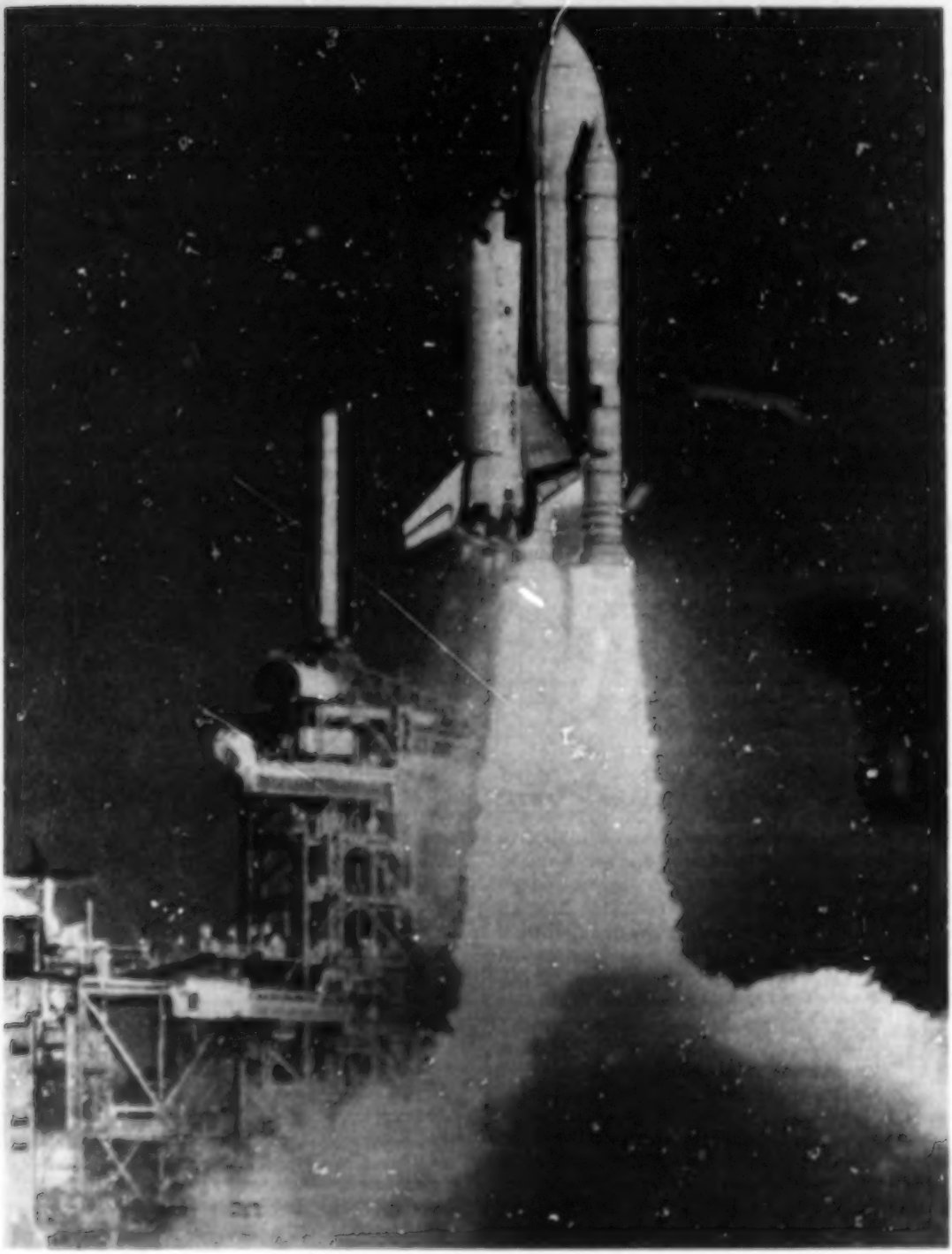
A. A. Sonnek, Acting Assistant Director—Helium Operations, Washington, D.C.
L. D. Bippus, Acting General Manager—Helium Operations, Amarillo, Tex.

The Federal Helium Program, as conducted by the Bureau of Mines under the Helium Act Amendments of 1960 (Public Law 86-777), provides for the current and foreseeable future needs for helium for essential Government activities and fosters individual enterprise in the production and distribution of helium. Facilities for carrying out the program include processing plants at Keyes, Okla., and Masterson and Amarillo, Tex.; the Cliffside helium storage reservoir near Amarillo; the analytical services laboratory at the Amarillo plant; 525 miles of high-pressure helium and natural gas pipelines in Texas, Oklahoma, and Kansas; and a pipeline maintenance station at Satanta, Kans.

This year, 250 million cubic feet (MMcf) of helium was produced and distributed to support Federal programs, such as three NASA space shuttle launches, DOD's advanced weapons research and development, and DOE's next-generation energy conversion research and development. Federal helium sales were at an 11-year high. About 190 MMcf was used as gas and 60 MMcf as liquid. The growing Federal liquid helium market was met by production from new, larger, more efficient equipment. All of this helium was extracted from gas withdrawn from the Cliffside Field. Under the terms of 13 storage contracts with private firms, about 160 MMcf of helium was stored in the Cliffside Field and approximately 625 MMcf was redelivered to relieve a private industry shortage of crude helium. Eight contracts were active during the year. One hundred MMcf of the helium redelivered to private industry was purified by the Bureau. The Cliffside reservoir contains approximately 40 billion cubic feet (Bcf) of helium stored for future Government use. As part of the Bureau's continuing helium resources evaluation program, 260 natural gas samples obtained from 23 states were analyzed for helium.

Drilling continued in the Tip Top Field in Sublette County, Wyoming, the largest nondepleting Federal helium resource. Four wells were expected to be completed in the deep helium-rich gas reservoirs in the Tip Top Field vicinity by the end of 1982. These are in addition to the seven wells completed in the area since 1979. It is expected that the deep gas will be produced, beginning about 1987. Helium resources in the Tip Top Field are now estimated at over 60 Bcf and, as more wells are drilled, an increase in this estimate is likely. This resource is currently not in production and constitutes about half of the nondepleting resources. If, as expected, production begins in the near future, this resource will be removed from the nondepleting classification. Almost all of the Tip Top helium-bearing natural gas is located on Federal lands and title to the contained helium is held by the Federal Government. Options for conserving the federally owned helium are being evaluated.

Analysis of helium and helium mixtures was improved by the modification and development of analytical techniques. Details of a patented automatic continuous transducer-drift compensator to improve the reliability of endpoint monitoring systems were published. A method was developed for preparing gravimetric primary standard mixtures in the parts-per-trillion range to determine the abundance of helium-3 and helium-4 in geochemical samples and isotopically purified helium-4. A precise reliable method was developed for determining helium in water for use in sampling and analyzing surface and subsurface waters for geochemical survey work. Private exploration companies have expressed an interest in the Bureau's sampling and analytical techniques.



Bureau helium is used to purge the large external tank and pressurize liquid fuel to space shuttle engines.

Directory

Headquarters Officials

Mailing address: U.S. Department of the Interior
Bureau of Mines
2401 E Street, N.W.
Washington, D.C. 20241

Director	Robert C. Horton
Deputy Director	James F. McAvoy
Chief Staff Officer	John D. Morgan
Chief Scientist	Thomas A. Henrie
Chief Economist	Hermann Enzer
Assistant Director—Planning and Budget	Ralph C. Kirby
Assistant Director—Mining Research	Harry R. Nicholls (Acting)
Assistant Director—Minerals and Materials Research	William L. Miller
Assistant Director—Mineral Data Analysis	Walter G. Dupree (Acting)
Assistant Director—Minerals Information	V. Anthony Cammorata, Jr. (Acting)
Assistant Director—Helium Operations	Armond A. Sonnek (Acting)

Field Officials

Alaska Field Operations Center 13
P.O. Box 550
Juneau, Alaska 99802
(907) 364-2111
Chief: John J. Mulligan

Albany Research Center 1
1450 Queen Avenue, S.W.
P.O. Box 70
Albany, Oreg. 97321
(503) 967-5893
Research Director: Frenk E. Block

Avondale Research Center 5
4900 LaSalle Road
Avondale, Md. 20782
(301) 436-7501
Research Director: William J. Campbell

Boulder City Engineering Laboratory 11
500 Date Street
Boulder City, Nev. 89005
(702) 293-1033
Chief: William W. Stephens

Denver Research Center 9
Building 20, Denver Federal Center
Denver, Colo. 80225
(303) 234-3754
Research Director: Lewis V. Wade (Acting)

Eastern Field Operations Center 4
4800 Forbes Avenue
Pittsburgh, Pa. 15213
(412) 621-4500
Chief: Robert D. Thompson

Helium Field Operations 8
1100 South Fillmore Street
Amarillo, Tex. 79101
(806) 376-2606
General Manager: L. Dale Bippus (Acting)

Intermountain Field Operations Center 9
Building 20, Denver Federal Center
Denver, Colo. 80225
(303) 234-3918
Chief: Joseph B. Smith

Pittsburgh Research Center 4
Cochrans Mill Road
P.O. Box 18070
Pittsburgh, Pa. 15236
(412) 675-6601
Research Director: John N. Murphy

Reno Research Center 12
1605 Evans Avenue
Reno, Nev. 89520
(702) 784-5391
Research Director: Arthur F. Colombo

Rolla Research Center 7
1300 Bishop Avenue
P.O. Box 280
Rolla, Mo. 65401
(314) 364-3169
Research Director: Danton L. Paulson (Acting)

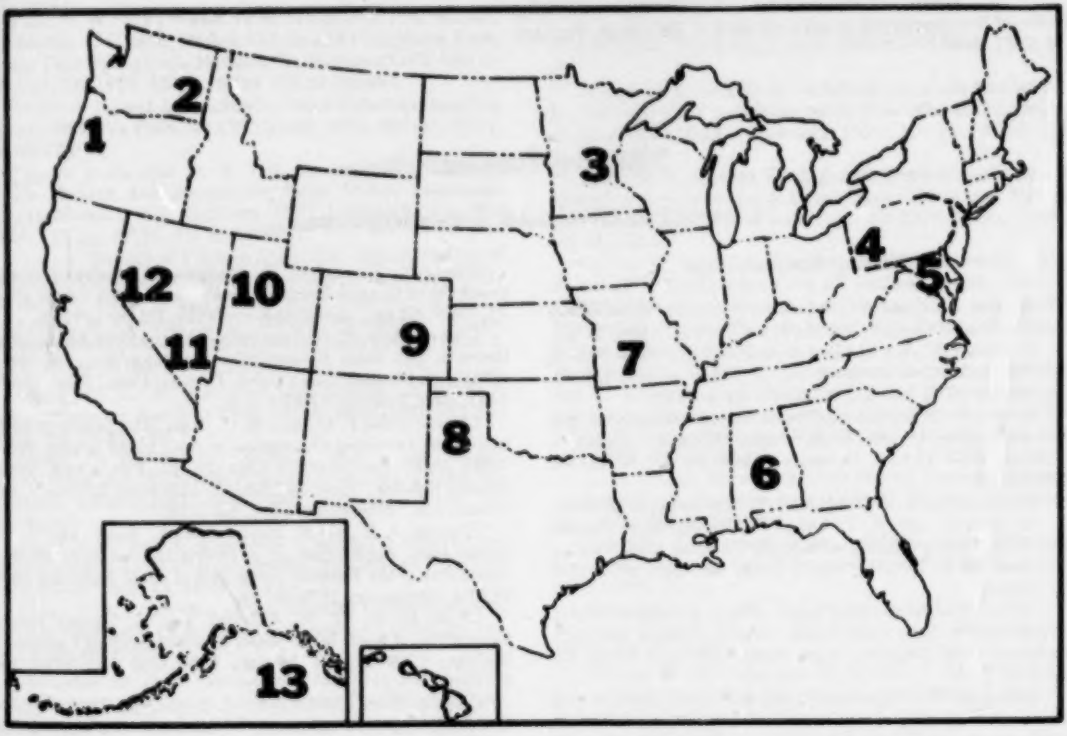
Salt Lake City Research Center 10
729 Arapeen Drive
Salt Lake City, Utah 84108
(801) 524-6100
Research Director: William A. McKinney

Spokane Research Center 2
E. 315 Montgomery Avenue
Spokane, Wash. 99207
(509) 484-1610
Research Director: Douglas D. Bolstad

Tuscaloosa Research Center 6
P.O. Box L
University, Ala. 35486
(205) 758-0491
Research Director: Martin H. Stanczyk

Twin Cities Research Center 3
5629 Minnehaha Avenue South
Minneapolis, Minn. 55417
(612) 725-4610
Research Director: John W. Corwine

Western Field Operations Center 2
E. 360 Third Avenue
Spokane, Wash. 99202
(509) 456-5350
Chief: Gary A. Kingston



Recent Publications and Patents

Results of Bureau investigations are published as Reports of Investigations (RI's), Information Circulars (IC's), Technical Progress Reports (TPR's), and Bulletins. Many of these publications are available at no cost and can be obtained by writing—

Section of Publications
Bureau of Mines
U.S. Department of the Interior
4800 Forbes Avenue
Pittsburgh, Pa. 15213

Reprints or copies of papers published in technical journals and other media are not generally available for distribution; specific requests for these papers should be made directly to the authors involved. Items such as Open File Reports (OFR's) listed as available from NTIS may be obtained from the National Technical Information Service, Springfield, Va. 22161; the PB number should be given when ordering. OFR's not listed as available from NTIS are available for reference at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C., and the field facilities listed in the directory.

The following listing, which is organized to parallel the format used in the research summaries, includes many of the publications and patents issued on Bureau developments during the past 3 years. Additional information on any given subject can be obtained by contacting the investigators named in the research summaries or the authors of any of the following papers.

Mining Research

Conservation and Development

Mining Technology

Ahlness, J. K., and J. C. Kirchner. Electronic Ore-Sorting Tests on Native Copper Ore. BuMines RI 8490, 1980, 36 pp.

Archibald, W. R. Field Test of Hydraulic Borehole Mining Systems in Shallow Uranium Sands. BuMines OFR 136-80, September 1978, 215 pp.; NTIS, PB 81-128969.

Benson, H. S. Production Engineering, Development, and Demonstration of the Draft Power Sensor. Volume I. BuMines OFR 152-81, November 1980, 60 pp.; NTIS, PB 82-143165.

Brown, G. R., W. J. Douglas, E. T. Schroeder, D. H. Dike, A. H. Hirsch, and J. T. Urban. Environmental Factors Affecting Surface Mining of Steeply Pitching Coal Seams. BuMines OFR 39(1)-81, April 1980, 131 pp.; NTIS, PB 81-194987.

———. Environmental Factors Affecting Surface Mining of Steeply Pitching Coal Seams. Volume II/Site Analysis. BuMines OFR 39(2)-81, April 1980, 129 pp.; NTIS, PB 81-194995.

Carnahan, T. G. Effects of Temperature on Simulated In Situ Leaching of a Chalcopyrite Ore. BuMines RI 8642, 1982, 16 pp.

Carnahan, T. G., and R. E. Lindstrom. Effects of Sodium Chloride Leach Solution Additive on Simulated In Situ Leaching of a Chalcopyrite Ore. BuMines RI 8626, 1982, 16 pp.

Chae, D. G., and M. E. Wadsworth. Modeling of the Leaching of Copper Oxide Ores. BuMines OFR 52-80, Dec. 31, 1979, 62 pp.; available from NTIS, PB 80-179120.

Chamberlain, P. G. Arizona's Artillery Peak Manganese Deposits and Their Potential for Leaching. Pres. at SME-AIME Fall Meeting and Exhibit, Denver, Colo., Nov. 18-20, 1981, SME Preprint 81-367, 8 pp.

Chamberlain, P. G., and M. G. Pojar. The Status of Gold and Silver Leaching Operations in the United States. Proc. 110th AIME Ann. Meeting, Chicago, Ill., Feb. 22-26, 1981, Special Volume, "Gold and Silver—Leaching, Recovery and Economics," September 1981, pp. 1-16.

Cheung, J. B., G. H. Hurlburt, L. E. Scott, and S. D. Veenhuizen. Application of a Hydraulic Borehole Mining Apparatus to the Remote Extraction of Coal. BuMines OFR 117-81, September 1976, 87 pp.

Clark, G. B., D. W. Ashcom, and K. Hanna. Rapid Excavation of Rock With Small Charges of High Explosive. BuMines OFR 111-80, January 1980, 250 pp.; NTIS, PB 81-125577.

Connell, J. P., C. M. Gibbs, C. L. Livesay, D. C. Mnytti, and J. M. Taipale. Evaluation, Modification and Application of Roadheaders in Underground Uranium Mines. BuMines OFR 64-81, 1980, 71 pp.

Cooley, W. C., and V. Ter-Minassian. Survey of Surface Hydraulic Mining Technology. Volume 1—Final Report. BuMines OFR 13(1)-80, 1976, 134 pp.

_____. Survey of Surface Hydraulic Mining Technology. Volume 2—Appendices to Final Report. BuMines OFR 13(2)-80, 1976, 410 pp.

Dareing, D. W., E. T. Wood, D. H. Davidson, and W. C. Larson. Drilling and Completing Multiple Branched Boreholes for In Situ Leach Mining. Pres. at Energy-Source Techol. Conf. and Exhibition, Houston, Tex., Jan. 18-22, 1981, ASME Preprint 81-Pet-2, 8 pp.

Dick, R. A., and S. P. Wimpfen. Oil Mining. Sci. Am., v. 243, No. 4, October 1980, pp. 156-161.

Dolinar, D. R., F. G. Horino, and V. E. Hooker. Mechanical Properties of Oil Shale and Overlying Strata, Naval Oil Shale Reserve, Anvil Points, Colo. BuMines RI 8608, 1982, 43 pp.

Farris, C. B. Natural Cementation of Retorted Oil Shale. BuMines OFR 54-80, May 1979, 131 pp.; NTIS, PB 80-179138.

Fewkes, R. H., W. D. McFarland, W. R. Reinhart, and R. K. Sorem. Development of a Reliable Method for Evaluation of Deep Sea Manganese Nodule Deposits. BuMines OFR 64-80, Jan. 12, 1979, 94 pp.; NTIS, PB 80-182116.

_____. Evaluation of Metal Resources at the Near Proposed Deep Sea Mine Sites. BuMines OFR 108-80, Feb. 15, 1980, 239 pp.; NTIS, PB 80-228992.

Fewkes, R. H., W. D. McFarland, and R. K. Sorem. Manganese Nodule Resource Data, Sea Scope Expedition. BuMines OFR 144-81, June 15, 1981, 230 pp.; NTIS, PB 82-142571.

Fisk, M. B., J. Z. Frazer, J. S. Elliott, and L. L. Wilson. Availability of Copper, Nickel, Cobalt and Manganese From Ocean Ferromanganese Nodules (II). BuMines OFR 149(1)-80, Aug. 24, 1979, 63 pp.; NTIS, PB 81-145963.

Foote, A. L., and J. S. Schaefer. Mine Materials Handling Vehicle (MMHV). BuMines OFR 59-80, 1978, 308 pp.; NTIS, PB 80-178890.

Frazer, J. Z., and M. B. Fisk. Availability of Copper, Nickel, Cobalt and Manganese From Ocean Ferromanganese Nodules (III). BuMines OFR 140(2)-80, Aug. 31, 1980, 112 pp.; NTIS, PB 81-145971.

_____. Geological Factors Related to Characteristics of Seafloor Manganese Nodule Deposits. BuMines OFR 142-80, Apr. 30, 1980, 41 pp.; NTIS, PB 81-145831.

Frazer, J. Z., and L. L. Wilson. Manganese Nodule Deposits in the Indian Ocean. BuMines OFR 141-80, Sept. 1, 1979, 70 pp.; NTIS, PB 81-145849.

Grant, D. C. In Situ Leaching Studies of Uranium Ores—Phase V. BuMines OFR 84-81, May 1980, 593 pp.; NTIS, PB 81-222739.

Grote, P. B., W. A. Coleman, and G. M. Guard. Alternatives for Technology Transfer to the Enterprise. BuMines OFR 84-80, July 1980, 121 pp.; NTIS, PB 80-209497.

Grote, P. B., and W. Gaymann. A Technical Basis for the Development of Deep Ocean Mining Regulations. BuMines OFR 87-80, Sept. 14, 1979, 310 pp.

Guay, P. J. Evaluation of the Kloswall Longwall Mining System. BuMines OFR 102-80, September 1978, 21 pp.; NTIS, PB 80-227622.

Houseknecht, D. W. Comparative Anatomy of a Pottsville Lithic Arenite and Quartz Arenite of the Pocahontas Basin, Southern West Virginia. Petrogenic, Depositional, and Stratigraphic Implications. J. Sediment. Petrol., v. 50, No. 1, March 1980, pp. 3-20.

Houseknecht, D. W., M. A. Kuhn, A. P. Matteo, Jr., D. J. Steyaert, J. F. Zaengle, and A. T. Iannacchione. High-Constructive, Tidally Influenced Deltaic Sedimentation in Arkoma Basin: Desmoinesian Hartshorne Sandstone. Am. Assoc. Pet. Geol. Bull., v. 65, No. 8, August 1981, p. 1499.

Jackson, P., H. Bennett, A. Liskow, R. Schuchman, R. Turpening, and L. Wilock. Geophysical Techniques Applied to Oil Shale Mining Operations. BuMines OFR 57-80, February 1978, 251 pp.

Johnson, G. A. Closed Circuit Television Improves Shovel Productivity, Aids Maintenance. Min. Equipment Internat., v. 4, No. 8, October 1980, pp. 38-41.

_____. Improved Loading Shovel Productivity Using Ruggedized Closed Circuit Television. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-407, 12 pp.

Johnson, R. N. In-Pit Crushing and Conveying With Movable Crushers. BuMines OFR 35-82, November 1980, 213 pp.; NTIS, PB 82-184714.

Kaplan, M., and D. Chazin. Potential Applications of Drill-Split Fragmentation Systems in Underground Mines. BuMines OFR 86-80, Aug. 20, 1979, 188 pp.; NTIS, PB 80-210792.

Kauffman, P. W., S. A. Hawkins, and R. R. Thompson. Room and Pillar Retreat Mining. A Manual for the Coal Industry. BuMines IC 8849, 1981, 228 pp.

Kaufman, W. W., D. N. Reynolds, and J. J. Noll. Topsoil Rock Removal Technology. BuMines OFR 73-80, Oct. 31, 1979, 106 pp.; NTIS, PB 80-204571.

Kaufman, W. W., and W. D. Shrader. Development of Improved Multiseam Contour Haulback Mining. BuMines OFR 5-80, 1979, 347 pp.; NTIS, PB 80-149354.

Kneisley, R. O. Rock Mechanics Investigation of Two-Bed Trona Mining, Green River, Wyo. BuMines RI 8598, 1982, 22 pp.

Knoke, G. S., and W. R. Archibald. Borehole Mining: An Environmentally Compatible Method for Mining Oil Sands. BuMines OFR 50-81, February 1980, 114 pp.; NTIS, PB 81-214231.

Lambert, J. E., and P. Mighdoll. Feasibility of Control System Automation for a Drum Head Continuous Mining Machine. BuMines OFR 8-81, Aug. 10, 1979, 97 pp.; NTIS, PB 81-168361.

Larson, W. C., W. W. Svendsen, J. F. Hoffmeister, and R. E. Cozad. A Retractable Core Bit Drilling System. Pres. at 109th AIME Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980, SME Preprint 80-116, 16 pp.; Min. Eng., v. 34, No. 2, February 1982, pp. 163-170.

Leonard, F., C. Simon, M. Stoddard, M. Verma, M. White, and L. Welborn. Area Terrace Pit Coal Mining Systems. Volume 1—Technical & Economic Evaluation of Terrace Pit Mining Systems. BuMines OFR 15(1)-82, October 1980, 296 pp.; NTIS, PB 82-166471.

_____. Area Terrace Pit Coal Mining Systems. Volume 2—Appendices. BuMines OFR 15(2)-82, October 1980, 448 pp.; NTIS, PB 82-166489.

Lindroth, D. P., and S. J. Anderson. Safe, Effective Hangup Clearance for Underground Mines. BuMines RI 8651, 1982, 12 pp.

Mangolds, A., and A. Fisk. Undercut and Fill System for Pitching Coal. BuMines OFR 57-82, June 1981, 94 pp.; NTIS, PB 82-200486.

Merritt, R., H. Peterson, C. Wentz, T. Licht, and M. Harris. Heap Leaching Studies on Uranium Ore. Phase VI: Field-Scale Leaching Test Program. BuMines OFR 117-80, February 1980, 130 pp.; NTIS, PB 81-129751.

Miller, H. J., E. E. Laughbaum, and W. R. Fisher. Portable Crusher for Underground Mining Applications and Design. Phase I—Design. BuMines OFR 100-80, Aug. 31, 1978, 111 pp.; NTIS, PB 80-227515.

Nigbor, M. T., W. E. Engelmann, and D. R. Tweeton. Case History of a Pilot-Scale Acidic In Situ Uranium Leaching Experiment. BuMines RI 8652, 1982, 81 pp.

Nunenkamp, D. C., and W. C. Cooley. Survey of Coal Preparation Technology for Hydraulic Coal Mines. BuMines OFR 13(3)-80, 1976, 455 pp.

Peng, S. S., and R. E. Thill. Stress Distribution and Pillar Design in Oil Shale Retorts. BuMines RI 8597, 1982, 33 pp.

Peterson, D. R., and P. B. Grote. Study of Deep Ocean Mining Operational Economics. Vol. I. Simulation Development and Study of Obstacle Effects. BuMines OFR 95(1)-80, September 1979, 58 pp.; NTIS, PB 80-219470.

——— Study of Deep Ocean Mining Operational Economics. Vol. II. Deep Ocean Mining Operational Simulation (DOMOPS) User's Manual. BuMines OFR 95(2)-80, September 1979, 56 pp.; NTIS, PB 80-219488.

Phillips, S. H. E. Development of an Impact Rock Breaker Shaft Sinking System. BuMines OFR 20-82, June 1981, 87 pp.

Potter, G. M., C. K. Chase, and P. G. Chamberlain. Feasibility of In Situ Leaching of Metallic Ores Other Than Copper and Uranium. Pres. at SME-AIME Fall Meeting and Exhibit, Denver, Colo., Nov. 18-20, 1981, SME Preprint 81-363, 6 pp.

Savanick, G. A. Borehole Mining of Deep Phosphate Ore. U.S. Bureau of Mines and the Fertilizer Institute Phosphate Workshop, Tuscaloosa, Ala., Mar. 16-17, 1982, pp. 3-6.

Savanick, G. A., and W. G. Krawza. Water Jet Perforation. A New Method for Completing and Stimulating In Situ Leaching Wells. BuMines RI 8569, 1981, 30 pp.

Schmidt, R. D. Computer Modeling of Fluid Flow During Production and Environmental Restoration Phases of In Situ Uranium Leaching. BuMines RI 8479, 1980, 70 pp.

Schmidt, R. L. U.S. Bureau of Mines Develops Portable Crusher for Underground Hardrock Mines. Eng. and Min. J., v. 183, No. 1, January 1982, pp. 72-75.

Simpson, D. G., and W. T. Plass (comp.). Proceedings of Seminar on the Role of Overburden Analysis in Surface Mining, Wheeling, W. Va., May 6-7, 1980. Sponsored by the American Council for Reclamation Research and the Bureau of Mines. BuMines IC 8863, 1982, 51 pp.

Snodgrass, J. J. A New Sonic Velocity-Logging Technique and Results in Near-Surface Sediments of Northeastern New Mexico. BuMines TPR 117, 1982, 24 pp.

St. John, C. M., M. Christianson, and D. L. Peterson. Evaluation of Mine Parameters for Copper-Nickel Deposits of Northern Minnesota. BuMines OFR 10-80, Feb. 15, 1979, 112 pp.; NTIS, PB 80-144074.

Svendsen, W. W., R. E. Cozad, and J. F. Hoffmeister. Retractable Bit System. BuMines OFR 119-81, Dec. 20, 1980, 105 pp.; NTIS, PB 81-104340.

Toth, G. W., and W. C. Larson. Cost and Sensitivities Analysis of Uranium In Situ Leach Mining. Pres. at SME-AIME Fall Meeting and Exhibit, Denver, Colo., Nov. 18-20, 1981, SME Preprint 81-361, 6 pp.

Touseull, J., and C. Rich, Jr. Documentation and Analysis of a Massive Rock Failure at the Bautsch Mine, Galena, Ill. BuMines RI 8453, 1980, 49 pp.

Tweeton, D. R., T. Gullinger, W. M. Breland, and R. S. Schechter. The Advantages of Conditioning an Orebody With a Chloride Solution Before In Situ Uranium Leaching With a Carbonate Solution. Pres. at 55th Ann. Tech. Conf. and Exhibition, SPE-AIME, Dallas, Tex., Sept. 21-24, 1980, SPE Preprint 9490, 4 pp.

Tweeton, D. R., and K. A. Peterson. Selection of Lixiviants for In Situ Uranium Leaching. BuMines IC 8851, 1981, 35 pp.

U.S. Bureau of Mines, Staff. In Situ Mining Research. Proceedings: Bureau of Mines Technology Transfer Seminar, Denver, Colo., August 5, 1981. BuMines IC 8852, 1981, 112 pp.

Utter, S. The Bureau of Mines Shaft and Research Facility in the Oil Shales of Colorado. Pres. at 83d National Western Min. Conf., Denver, Colo., Feb. 6-8, 1980: pub. in 1980 Mining Yearbook. Colorado Mining Association, Denver, June 1980, pp. 164-170.

——— A Range of Mining Techniques to Meet Site-Specific Conditions. Min. Eng., v. 33, No. 1, January 1981, pp. 30-43.

Veith, D. L. Hypothetical Mine Models and Input-Output Requirements for Copper-Nickel Mining in Minnesota. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-330, 21 pp.

Wardell, K., P. Eynon, and C. Wardell. Technological Investigations To Develop Design Criteria for the Optimum Size of Oil and Gas Well Blocks. BuMines OFR 147-81, Feb. 8, 1980, 130 pp.

Watson, W. I., E. Ohlsson, C. E. Shorey, R. J. Miller, and A. J. Whittier. Study of the Slate Mining Industry of Vermont/New York. BuMines OFR 125-80, Oct. 15, 1980, 172 pp.; NTIS, PB 81-128936.

Resource Conservation Technology

Akens, G., J. Metz, and P. Bilzi. Technical and Economic Evaluation of Mine Closure Procedures. Final Report. BuMines OFR 153-81, June 1980, 281 pp.; NTIS, PB 82-136995.

Andrews, D. E., J. L. Withiam, E. F. Perry, and H. L. Crouse. Environmental Effects of Slaking of Surface Mine Spoils: Eastern & Central United States. BuMines OFR 146-80, September 1980, 250 pp.; NTIS, PB 81-168718.

Backer, R. R., and R. A. Busch. Final Coal-Refuse Slurry Dewatering. BuMines RI 8581, 1981, 18 pp.

Bainbridge, K. L., M. A. Wilkinson, and B. M. Mahar. Evaluation of Lixiviation of Mine Wastes. BuMines OFR 73-81, December 1980, 239 pp.; NTIS, PB 81-222515.

Bandholz, G. M. Massive Sulfide Tailing Disposal Using the Thickened Discharge Method. BuMines OFR 146-81, June 1981, 229 pp.

Banks, P. T., R. E. Nickel, and D. A. Blome. Reclamation and Pollution Control: Planning for Small Sand and Gravel Mining Operations. BuMines OFR 35-81, Jan. 31, 1981, 159 pp.; NTIS, PB 81-190241.

Bayne, J. N., and H. Lawrence. Application of Satellite Data to Surface Mine Monitoring in Selected Counties of South Carolina. BuMines OFR 11-80, March 1979, 141 pp.; NTIS, PB 80-144629.

Bohn, R., T. Cuscino, D. Lane, F. Pendelton, and R. Hackney. Dust Control for Haul Roads. BuMines OFR 130-81, February 1981, 146 pp.; NTIS, PB 82-116666.

Bucek, M. F., J. K. Clauser, J. A. Schad, and N. K. Charkavorti. Technical and Economic Evaluation of Underground Disposal of Coal Mine Wastes. BuMines OFR 15-80, January 1980, 372 pp.; NTIS, PB 80-154768.

Carey, D. L., and R. L. Lappi. Recontouring of Steep-Slope Abandoned Contour Mines. Volume I—Summary. BuMines OFR 11(1)-82, August 1981, 65 pp.; NTIS, PB 82-168048.

——— Recontouring of Steep-Slope Abandoned Contour Mines. Volume II—Appendices. BuMines OFR 11(2)-82, August 1981, 227 pp.; NTIS PB 82-168055.

Colaizzi, G. J., R. H. Whaite, and D. L. Donner. Pumped-Slurry Backfilling of Abandoned Coal Mine Workings for Subsidence Control at Rock Springs, Wyo. BuMines IC 8846, 1981, 100 pp.

Chaiken, R. F. Controlled Burnout of Wasted Coal on Abandoned Coal Mine Lands. BuMines RI 8478, 1980, 23 pp.

Clar, M. L., J. J. Ferrandino, and C. Bosma. Feasibility of Water Diversion and Overburden Dewatering. Volume I: Technical Report. BuMines OFR 103(1)-82, April 1981, 231 pp.

———. Feasibility of Water Diversion and Overburden Dewatering. Volume II: Annotated Bibliography. BuMines OFR 103(2)-82, April 1981, 113 pp.

Dewey, R. S., L. A. Robbins, L. D. Oehler, T. L. Reed, and P. A. Bilzi. A Study of Hazardous Openings to Abandoned Underground Mines in Western Colorado. Volume I. Final Report. BuMines OFR 21(1)-81, April 1980, 218 pp.; NTIS, PB 81-177909.

———. A Study of Hazardous Openings to Abandoned Underground Mines in Western Colorado. Volume II. Final Appendix A Through L. BuMines OFR 21(2)-81, April 1980, 370 pp.; NTIS, PB 81-177917.

———. A Study of Hazardous Openings to Abandoned Underground Mines in Western Colorado. Volume III. Final Appendix M Through W. BuMines OFR 21(3)-81, April 1980, 334 pp.; NTIS, PB 81-177925.

———. A Study of Hazardous Openings to Abandoned Underground Mines in Western Colorado. Volumes I Through III. BuMines OFR 21(1)—(3)-81 (set), April 1980, 922 pp.; NTIS, PB 81-177891 (set).

Dollhopf, D. J., J. D. Goering, C. J. Levine, B. J. Bauman, D. W. Hedberg, and R. L. Hodder. Selective Placement of Coal Stripmine Overburden in Montana. III. Spoil Mixing Phenomena. BuMines OFR 104(3)-80, July 1978, 79 pp.; NTIS, PB 81-103160.

Dollhopf, D. J., J. D. Goering, C. J. Levine, B. J. Bauman, and R. L. Hodder. Selective Placement of Coal Stripmine Overburden in Montana. IV. Hydrogeologic Studies. BuMines OFR 104(4)-80, July 1979, 58 pp.; NTIS, PB 81-103194.

Dollhopf, D. J., W. D. Hall, C. A. Cull, and R. L. Hodder. Selective Placement of Coal Stripmine Overburden in Montana. II. Initial Field Demonstration. BuMines OFR 104(2)-80, June 1977, 108 pp.; NTIS, PB 81-103178.

Dollhopf, D. J., W. D. Hall, W. M. Schafer, E. J. DePuit, and R. L. Hodder. Selective Placement of Coal Stripmine Overburden in Montana. I. Data Base. BuMines OFR 104(1)-80, June 1977, 116 pp.; NTIS, PB 81-103186.

Dowding, C. H., P. D. Murray, and D. K. Atmatzidis. Dynamic Properties of Residential Structures Subjected to Blasting Vibrations. J. Structures Div., ASCE, v. 107, July 1981, pp. 1233-1249.

Earnest, H. W., R. A. Heisler, H. L. Hoe, and V. Rajaram. Underground Disposal of Retorted Oil Shale for the Paraho Retorting Process. BuMines OFR 1-80, 1978, 379 pp.; NTIS, PB 80-128739.

Einstein, H. H., G. B. Baecher, D. Veneziano, H. C. Chan, W. S. Dershowitz, E. F. Glynn, J. L. Galzi, N. A. Lanney, K. O'Reilly, W. S. Scull, and P. Yip. Risk Analysis for Rock Slopes in Open Pit Mines. Part I. Distributions of Rock Mass Properties. BuMines OFR 46(1)-81, November 1979, 200 pp.; NTIS, PB 81-200592.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part II. Limit Equilibrium Analysis for Rock Wedge Stability. BuMines OFR 46(2)-81, November 1979, 182 pp.; NTIS, PB 81-201600.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part III. Reliability Analysis of Rock Slope Stability. BuMines OFR 46(3)-81, November 1979, 354 pp.; NTIS, PB 81-201618.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part IV. Field Exploration To Determine Rock Mass Properties. BuMines OFR 46(4)-81, November 1979, 176 pp.; NTIS, PB 81-201626.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part V. Probabilistic Models of Jointed Rock Mass Deformation and Their Implications. BuMines OFR 46(5)-81, November 1979, 113 pp.; NTIS, PB 81-201634.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part VI. Executive Summary, Introduction and Technical Summary, Bibliography. BuMines OFR 46(6)-81, November 1979, 63 pp.; NTIS, PB 81-201642.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part VII. Appendices A Through M, Detailed Geologic Data Underlying Developments. BuMines OFR 46(7)-81, November 1979, 394 pp.; NTIS, PB 81-201659.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Part VIII. Appendix UM, User's Manual for Computer Programs. BuMines OFR 46(8)-81, November 1979, 453 pp.; NTIS, PB 81-201667.

———. Risk Analysis for Rock Slopes in Open Pit Mines. Parts I Through VIII. BuMines OFR 46(1)—(8)-81 (set), November 1979, 1954 pp.; NTIS, PB 81-201584 (set).

Engelmann, W. H., P. E. Phillips, D. R. Tweeton, K. W. Loest, and M. T. Nigbor. Restoration of Ground Water Quality Following Pilot-Scale Acidic In Situ Uranium Leaching at Nine-Mile Lake Site Near Casper, Wyoming. Pres. at 55th Ann. Tech. Conf. and Exhibition, SPE-AIME, Dallas, Tex., Sept. 21-24, 1980, SPE Preprint 9494, 24 pp.

Feldstein, N. Surface Chemical Technology for Improved Wetting of Coal Dust. BuMines OFR 127-81, February 1981, 50 pp.; NTIS, PB 82-104654.

Foster-Miller Associates, Inc. Detailed Design and Demonstration of Underground Disposal of Coal Mining Wastes. Phase I. BuMines OFR 48-82, April 1981, 87 pp.

Freeman, W. G., R. M. Jones, J. G. Babcock, M. L. Christo, and R. A. Noel. Hazardous Surface Openings to Abandoned Underground Mines—Nevada. BuMines OFR 85-81, June 1980, 747 pp.; NTIS, PB 81-223414.

Froisland, L. J., P. L. Placek, and M. B. Shirts. Restoration of Surface Vegetation on Uranium Wastes at Uravan, Colo. BuMines RI 8653, 1982, 13 pp.

Gartrell, R. J., and T. J. Crocker. Development of a Cross Pit Overburden and Waste Material Handling System. BuMines OFR 17-80, January 1977, 75 pp.; NTIS, PB 80-145998.

GEX Colorado Inc. Detailed Design and Demonstration of Underground Disposal of Coal Mining Wastes. Phase I Report. BuMines OFR 101-82, June 1981, 61 pp.

Groenewold, G. H., and B. W. Rehm. Instability of Contoured Surface-Mined Landscapes in the Northern Great Plains: Causes and Implications. BuMines OFR 145-80, Sept. 1, 1980, 26 pp.

Gupta, V. L., and M. J. Miles. Containment Pond Technology. State-of-the-Art. BuMines OFR 94-80, December 1979, 74 pp.; NTIS, PB 80-223175.

Herbert, T. A., and R. G. Turner. Abandoned Mine Reclamation. A Case Study at Live Oak, Florida. BuMines OFR 75-82, May 30, 1981, 115 pp.; NTIS, PB 82-213901.

Hersloff, L. W. Baseline Environmental Monitoring Program for the Bear Creek Hydraulic Borehole Mining Demonstration Test. BuMines OFR 21-82, April 1981, 24 pp.

Hilton, E. W., and F. Frakes. Environmental Assessment

of Surface Shortwall Mining. BuMines OFR 126-80, Dec. 21, 1979, 255 pp.; NTIS, PB 81-128928.

Jacobsen, S. P., W. Roshey, and E. L. Rau. Coal Waste Dewatering Systems. BuMines OFR 114-81, Feb. 6, 1981, 133 pp.; NTIS, PB 81-244501.

Jensen, D. E., R. D. Munson, L. L. Oriard, J. D. Rietman, and R. S. Wright. Underground Vibrations From Surface Blasting at Jenny Mine, Kentucky. BuMines OFR 41-80, Nov. 1, 1979, 102 pp.; NTIS, PB 80-168925.

Jessey, D. R., J. M. Stangl, D. H. Dike, G. R. Brown, and E. W. Schroeder. Control of Water Pollution From Surface Mining Operations. Volume I. BuMines OFR 161(1)-81, Jan. 31, 1981, 172 pp.; NTIS, PB 82-139304.

Jessey, D. R., J. M. Stangl, A. H. Hirsch, D. H. Dike, G. R. Brown, and E. W. Schroeder. Control of Water Pollution From Surface Mining Operations. Volume II. BuMines OFR 16(2)-81, Jan. 31, 1981, 275 pp.; NTIS, PB 82-139312.

Johnson, A. M., G. R. Alger, R. J. Hodek, K. S. Kim, G. F. Frantti, C. W. Schultz, and C. A. Rhoades. Piping Induced Subsidence at the Sherwood Mine in Northern Michigan. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-356, 8 pp.

Johnson, B. V., R. J. Seibel, and D. E. Siskind. Noise and Vibration Control for Surface Mines. Program Document. BuMines IC 8876, 1982, 9 pp.

Jones, D. A. Land Reclamation as Sculpture. BuMines OFR 25-82, Feb. 12, 1981, 101 pp.; NTIS, PB 82-183351.

Kasper, D. R., H. W. Martin, L. D. Munsey, R. B. Bhappu, and C. K. Chase. Environmental Assessment of In Situ Mining. BuMines OFR 101-80, December 1979, 294 pp.; NTIS, PB 81-106783.

Kaufman, W. W., and J. R. Williams. Study of Underground Coal Mine Waste Disposal Requirements in the United States. BuMines OFR 6-80, 1978, 250 pp.; NTIS, PB 80-134646.

Kehrman, R. F. Detection of Lixiviant Excursions With Geophysical Resistance Measurements During In Situ Uranium Leaching. BuMines OFR 5-81, December 1979, 157 pp.; NTIS, PB 81-171324.

Kehrman, R. F., A. J. Farstad, and D. R. Tweeton. Use of Resistivity Measurement to Monitor Lixiviant Migration During In Situ Uranium Leaching. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-338, 10 pp.

Kleinmann, R. L. P. Bactericidal Control of Acid Problems in Surface Mines and Coal Refuse. Proc. 1980 Symp. on Surface Mining Hydrology, Sedimentology and Reclamation, Lexington, Ky., Dec. 1-5, 1980, pp. 333-337.

Kleinmann, R. L., D. A. Crerar, and R. R. Pacelli. Biogeochemistry of Acid Mine Drainage and a Method to Control Acid Formation. Min. Eng, v. 33, No. 3, March 1981, pp. 300-306.

Koerner, R. M., and J. L. Rosenfarb. Feasibility of Fatigue Assessment of Block Walls From Laboratory Scale Methods. BuMines OFR 144-80, Sept. 1, 1980, 99 pp.; NTIS, PB 81-140139.

Kohli, K. K., S. S. Peng, and R. E. Thill. Surface Subsidence Due to Underground Longwall Mining in the Northern Appalchian Coal Field. Pres. at SME-AIME Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980, SME Preprint 80-53, 8 pp.; pub. in Longwall-Shortwall Mining, State of the Art, ed. by R. V. Ramani, 1981, pp. 99-105.

Kost, J. A., G. A. Shirey, and C. T. Ford. In-Mine Tests for Wetting Agent Effectiveness. BuMines OFR 30-82, December 1980, 190 pp.; NTIS, PB 82-183344.

Lappi, R. L., and G. M. Smrikarov. Selective Interburden Handling Techniques. Volume I—Summary. BuMines OFR 80(1)-81, September 1980, 125 pp.; NTIS, PB 81-221905.

———. Selective Interburden Handling Techniques. Volume II—Appendices. BuMines OFR 80(2)-81, September 1980, 321 pp.; NTIS, PB 81-221913.

Larson, W. C. Uranium In Situ Leach Mining—Environmental Controls. Proc. 1st Internat. Conf. on Uranium Mine Waste Disposal, Vancouver, B.C., Canada, May 19-21, 1980 (ed. by C. W. Brawner). American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1980, pp. 175-192.

Linehan, P., and J. F. Wiss. Vibration and Air Blast Noise From Surface Coal Mine Blasting. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-336, 6 pp.

Loy, L. D., Jr., C. E. Ettinger, M. R. Frakes, and D. J. Kremer. Development of New Design Concepts for Construction of Valley Fills. BuMines OFR 2-80, 1978, 160 pp.; NTIS, PB 80-126055.

Ludwig, J. P., M. C. Nelson, C. E. Ludwig, and W. Been. Cost and Time Analysis of the Mining and Environmental Requirements in the Premining Stage for Copper Mining in the Northern Highland, Wisconsin. BuMines OFR 25-80, 1979, 185 pp.; NTIS, PB 80-159163.

Marple, V., K. Rubow, and O. Lantto. Fugitive Dust Study of an Open Pit Coal Mine. BuMines OFR 24-82, September 1980, 150 pp.; NTIS, PB 82-183112.

Martin, E., and G. V. Sullivan. Characterization of Residues From Selected Coal Conversion Processes. BuMines RI 8501, 1980, 13 pp.

Marvin, M. H., G. S. Knoke, and W. R. Archibald. Backfilling of Cavities Produced in Borehole Mining Operations. BuMines OFR 4-81, August 1979, 78 pp.; NTIS, PB 81-171308.

McIntosh, G. E., and W. R. Hamon. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. Phase I: Premining Hydrologic and Water Quality Conditions. BuMines OFR 31-80, Dec. 22, 1979, 35 pp.; NTIS, PB 80-159510.

Meister, R. A., and R. L. Hoffman. Improving Surface Coal Refuse Disposal Site Inspections. BuMines OFR 54-81, September 1980, 297 pp.; NTIS, PB 81-215402.

Mentz, J. W., J. R. Williams, G. Ahnell, T. L. Reed, and G. W. Akens. Feasibility Study of Partial Flooding in Mined Out Areas for Mine Drainage Pollution Abatement. Final Report. BuMines OFR 26-82, September 1981, 143 pp.; NTIS, PB 82-183401.

Miller, R. P., P. M. Douglass, R. A. Robinson, D. A. Roberts, and W. T. Laprade. Surface Mine Spoil Stability Evaluation, Interior Coal Province. Volume I—Main Report. Glossary of Terms (Appendix A) & Annotated Bibliography (Appendix B). BuMines OFR 78(1)-80, August 1979, 330 pp.; NTIS, PB 80-211113.

———. Surface Mine Spoil Stability Evaluation, Interior Coal Province, Volume II—Details of Mine Visits & Detailed Procedures of Laboratory Testing (Appendix C). BuMines OFR 78(2)-80, August 1979, 398 pp.; NTIS, PB 80-2111[illegible]

Miller, R. J., F.-D. Wang, T. Sladek, and C. Young. The Effect of In Situ Retorting on Oil Shale Pillars. BuMines OFR 120-89, March 1979, 194 pp.

Moebs, N. N. Subsidence Over Four Room-and-Pillar Sections in Southwestern Pennsylvania. BuMines RI 8645, 1982, 23 pp.

Moore, R. C., and M. A. Nawrocki. Effects of Subsidence From Thick Seam Coal Mining on Hydrology. BuMines OFR 93-80, Mar. 7, 1980, 245 pp.; NTIS, PB 80-219280.

Moore, R. C., N. J. Opper, M. D. Paul, and R. L. Kort. Environmental Instrumentation in Mining Air and Water. BuMines OFR 33-82, Aug. 28, 1981, 335 pp.; NTIS, PB 82-187139.

Nebgen, J. W., and D. F. Weatherman. Evaluation of Chemical Agents for Inhibiting Acid Mine Drainage Formation. BuMines OFR 49-80, 1979, 127 pp.; NTIS, PB 80-176357.

Nebgen, J. W., D. F. Weatherman, and W. H. Engelman. Inhibition of Acid Mine Drainage Formation: The Role of Insoluble Iron Compounds. Pres. at Inst. Environ. Sci. Ann. Meeting, Philadelphia, Pa., May 11-14, 1980; pub. in J. Environ. Sci., v. 24, No. 3, May-June 1981, pp. 23-27.

Ogasawara, C., G. F. Kuncir, and D. A. Lewis. Oil Shale Mining Environmental Research Program Overview. BuMines OFR 58-80, June 1979, 64 pp.; NTIS, PB 80-179112.

O'Rourke, J. E., and K. O'Connor. Dewatering Systems for Surface Coal Mines. BuMines OFR 32-80, Dec. 21, 1979, 260 pp.; NTIS, PB 80-160153.

Ozdemir, L., D. Ropchan, R. Miller, F. D. Wang, T. Sladek, C. Young, J. DuBow, and D. Fauysett. The Effect of In Situ Retorting on Oil Shale Pillars. BuMines OFR 76-82, October 1981, 387 pp.; NTIS, PB 82-214099.

Pearson, M. L., T. Preber, and P. J. Conroy. Outcrop Barrier Design Guidelines for Appalachian Coal Mines. BuMines OFR 134-81, Feb. 6, 1981, 167 pp.; NTIS, PB 82-113838.

Perrotti, A. E., and A. J. Snyder. Pilot Scale On-Site Evaluation of Activated Carbon for Rapid Oxidation of Ferrous Iron in Acid Mine Water. BuMines OFR 58-82, October 1981, 69 pp.; NTIS, PB 82-200494.

Perry, R. D., and F. C. Kresse. Development of Methods for Reclaiming Tailings Ponds and Dams. Volume I. BuMines OFR 40(1)-82, June 1981, 34 pp.; NTIS, PB 82-195736.

———. Development of Methods for Reclaiming Abandoned Tailings Ponds and Dams. Volume II. BuMines OFR 40(2)-82, June 1981, 378 pp.

Peters, W. R., T. M. Campbell, and V. R. Sturdivant. Detection of Coal Mine Workings Using High-Resolution Earth Resistivity Techniques. BuMines OFR 55-81, Sept. 26, 1980, 80 pp.; NTIS, PB 81-215378.

Powell, L. R. Longwall Subsidence Case History Number 1: Northern Appalachian Coal Region. BuMines OFR 124(1)-81, August 1981, 12 pp.

———. Longwall Subsidence Case History Number 2: Northern Appalachian Coal Region. BuMines OFR 124(2)-81, August 1981, 12 pp.

———. Longwall Subsidence Case History Numbers 3 and 4. Northern Appalachian Coal Region. BuMines OFR 145-81, February 1981, 17 pp.

Ritchey, J., F. H. Hagenbuch, and J. Mantel. The Development of a Cross-Pit Overburden Handling System. Volume I—Preliminary Design. BuMines OFR 3(1)-80, 1976, 68 pp.; NTIS, PB 80-132814.

———. The Development of a Cross-Pit Overburden Handling System. Volume II—Appendix. BuMines OFR 3(2)-80, 1976, 117 pp.; NTIS, PB 80-132822.

Robertson, D. A., J. A. Gould, J. A. Straw, and M. A. Dayton. Survey of Blasting Effects on Ground Water Supplies in Appalachia. Volume I. BuMines OFR 8(1)-82, November 1980, 161 pp.; NTIS, PB 82-152125.

———. Survey of Blasting Effects on Ground Water Supplies in Appalachia. Volume II. BuMines OFR 8(2)-82, November 1980, 266 pp.; NTIS, PB 82-152133.

Roth, J., K. C. Britton, R. W. Campbell, and W. R. Kettler. Evaluation of Surface Mining Blasting Procedures. BuMines OFR 18-80, June 6, 1978, 162 pp.; NTIS, PB 80-148653.

Rudchenko, S., R. Upsahl, J. P. Asby, and G. A. Mathieson. Conceptual Designs of Retaining Structures for Open Pit Backfilling. BuMines OFR 96-81, February 1981, 170 pp.; NTIS, PB 81-225799.

Savanick, G. A. Ground Water Impact of Borehole Mining. U.S. Bureau of Mines and the Fertilizer Institute Phosphate Workshop, Tuscaloosa, Ala., Mar. 16-17, 1982, pp. 10-13.

Science Management Corp. Analysis of Industry Research and Development Recommendations in Mining and Reclamation Technology. BuMines OFR 55-80, 1979, 168 pp.

Sherman, R. M., J. A. Kinkead, G. J. Campbell, and G. M. Adler. Irrigation for Reclamation of Strip Mined Lands. BuMines OFR 12-82, July 1980, 129 pp.; NTIS, PB 82-163395.

Siskind, D. E. Damage to Residential Structures From Surface Mine Blasting. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-362, 17 pp.

———. Vibration and Noise From Blasting. Proc. Inter-Noise 82, Internat. Inst. of Noise Control Eng., San Francisco, Calif., May 17-19, 1982, pp. 281-284.

Siskind, D. E., V. J. Stachura, M. S. Stagg, and J. W. Kopp. Structure Response and Damage Produced by Airblast From Surface Mining. BuMines RI 8485, 1980, 111 pp.

Siskind, D. E., M. S. Stagg, J. W. Kopp, and C. H. Dowding. Structure Response and Damage Produced by Ground Vibration From Blasting. BuMines OFR 105-80, Aug. 20, 1980, 176 pp.

———. Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting. BuMines RI 8507, 1980, 74 pp.

Sprute, R. H. Slimes Consolidation at the Henderson Mine. BuMines RI 8441, 1980, 20 pp.

Sprute, R. H., and D. J. Kelsh. Dewatering Fine-Particle Suspensions With Direct Current. Pres. at SME-AIME Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980; Proc. Fine Particles Processing Symp., American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 2, ch. 91, May 1980, pp. 1828-1844.

———. Electrokinetic Densification of Solids in a Coal Mine Sediment Pond—A Feasibility Study (In Two Parts). 1. Laboratory and Field Tests. BuMines RI 8666, 1982, 32 pp.

Stachura, V. J., D. E. Siskind, and A. J. Engler. Airblast Instrumentation and Measurement Techniques for Surface Mine Blasting. BuMines RI 8508, 1981, 53 pp.

Stagg, M. S., and A. J. Engler. Measurement of Blast-Induced Ground Vibrations and Seismograph Calibration. BuMines RI 8506, 1980, 62 pp.

Stinnett, L. A., M. R. Lawton, and W. F. Jennings. Hazardous Surface Openings to Abandoned Underground Mines, Black Hills National Forest. Volume I: Text, Appendices A & B. BuMines OFR 74(1)-80, Sept. 28, 1979, 171 pp.; NTIS, PB 80-204472.

———. Hazardous Surface Openings to Abandoned Underground Mines, Black Hills National Forest. Volume II: Appendix C: Abandoned Mine Identification Area A. BuMines OFR 74(2)-80, Sept. 28, 1979, 289 pp.; NTIS, PB 80-204480.

———. Hazardous Surface Openings to Abandoned Underground Mines, Black Hills National Forest. Volume III: Appendix C. Abandoned Mine Identification Areas B, C, and

D. BuMines OFR 74(3)-80, Sept. 28, 1979, 389 pp.; NTIS, PB 80-204498.

——— Hazardous Surface Openings to Abandoned Mines, Black Hills National Forest, Volumes I Through III. BuMines OFR 74(1)—(3)-80 (set), Sept. 28, 1979, 849 pp.; NTIS, PB 80-204464 (set).

Stewart, B. M., and L. A. Atkins. Engineering Properties of Combined Coarse and Fine Coal Wastes. BuMines RI 8623, 1982, 18 pp.

Tandanand, S., and L. R. Powell. Assessment of Subsidence Data From the Northern Appalachian Basin for Subsidence Prediction. BuMines RI 8630, 1982, 14 pp.

——— Consideration of Overburden Lithology for Subsidence Prediction. Proc. Workshop on Surface Subsidence Due to Underground Mining, Morgantown, W. Va., Nov. 30-Dec. 2, 1981, pp. 17-33.

Tesarik, D. R., and P. C. McWilliams. Factor of Safety Charts for Estimating the Stability of Saturated and Unsaturated Tailings Pond Embankments. BuMines RI 8564, 1981, 97 pp.

Towsend, F. C., D. J. Goodings, A. N. Schofield, and M. M. Al-Hussaini. Centrifugal Model Analysis of Coal Waste Embankment Stability. BuMines OFR 43-81, August 1980, 118 pp.; NTIS, PB 81-194524.

U.S. Bureau of Mines, Staff. Surface Coal Mining Reclamation Equipment and Techniques. Proceedings: Bureau of Mines Technology Transfer Seminars, Evansville, Ind., June 3, 1980, and Denver, Colo., June 5, 1980. BuMines IC 8823, 1980, 80 pp.

U.S. Bureau of Mines, Staff—Minerals Research. Mine Waste Disposal Technology. Proceedings: Bureau of Mines Technology Transfer Workshop, Denver, Colo., July 16, 1981. BuMines IC 8857, 1981, 70 pp.

U.S. Department of Agriculture. Research on the Hydrology and Water Quality of Watersheds Subject to Surface Mining. Phase I: Premining Hydrologic and Water Quality Conditions. BuMines OFR 88-80, July 1978, 347 pp.

Utter, S. Environmental Assessment of an Oil Shale Installation. Proc. 6th Ann. UMR-DNR Conf. on Energy, Rolla, Mo., Oct. 16-18, 1980, v. 6, pp. 481-485.

Utter, S. Stabilization of Oil Shale Waste Piles. Proc. Ann. UMR-DNR Conf. on Energy, Rolla, Mo., Oct. 14-16, 1980, pp. 301-308.

Wahler Associates. Engineering Property Changes and Environmental Effects on Coal Mine Wastes Due to Slaking. BuMines OFR 13-82, May 1981, 281 pp., NTIS, PB 82-163965.

Walsh, F. Investigation of the Mechanics of Mine Acid Formation in Underground Coal Mine Drainage. BuMines OFR 22-81, November 1980, 122 pp.; NTIS, PB 81-179418.

Williams, J. R., and R. J. Keenan. Water Handling Procedures for Reducing Acid Formation in Underground Coal Mines. BuMines OFR 156-81, Oct. 1, 1980, 106 pp.; NTIS, PB 82-137324.

Yardley, D. H., W. D. Lacabanne, and R. C. Nelson. Airborne From Taconite Tailings. BuMines OFR 148-81, November 1980, 53 pp.; NTIS, PB 82-143173.

Zahl, E. G., and G. L. Bloomsburg. Seepage Through Partially Saturated Soils Below a Uranium Tailings Pond. Proc. 1st Internat. Conf. on Uranium Mine Waste Disposal, Vancouver, British Columbia, Canada, May 19-21, 1980; American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, ch. 30, December 1980, pp. 445-455.

Zaitsoff, M. P., and C. L. Chiu. Model Demonstration of Drainage Structures for Safety of Mine Waste Impoundments. BuMines OFR 132-81, June 1981, 51 pp.

Health and Safety Technology

Respirable Dust

Burnett, M., R. J. Pokora, and T. Muldoon. Demonstration of a Dust Control System for Boom-Type Roadheaders. BuMines OFR 150-81, September 1981, 54 pp.; NTIS PB 82-143199.

Cecala, A. B., J. C. Volkwein, E. D. Thimons, and C. W. Urban. Protection Factors of the Airstream Helmet. BuMines RI 8591, 1981, 17 pp.

Cheng, L., and W. G. Cross. A Drop Impact Sampler. Environ. Sci. Technol., v. 15, No. 4, April 1981, pp. 459-463.

Courtney, W. G., J. Kost, and J. Colinet. Dust Deposition in Coal Mine Airways. BuMines TPR 116, 1982, 15 pp.

Divers, E. F., and J. T. Janosik. Scrubbers for Dust Control: A Comparison of Six Medium-Energy Use Types. BuMines RI 8449, 1980, 29 pp.

Divers, E. F., J. C. LaScola, and G. J. Hundman. New Twin Scrubber Installation for Continuous Mining Machines. BuMines TPR 112, 1981, 10 pp.

Gangal, M. D., and B. R. Banerjee. Deep Cutting Miner Production Tests. BuMines OFR 61-80, 1979, 86 pp., NTIS, PB 80-183932.

Grigal, D. J. Dust Collector on Longwall Shearer. BuMines OFR 57-81, February 1980, 81 pp.; NTIS, PB 81-214926.

Grigal, D. J., M. D. Blom, and D. F. Johnson. Dust Control for Cutter Machines. BuMines OFR 46-82, December 1981, 122 pp.; NTIS, PB 82-202706.

Johnson, G. G., Jr., and E. W. White. Characterization of Respirable Coal Mine Dust by Computer Analysis of Scanning Electron Microscope Images. BuMines OFR 56-80, July 1, 1979, 79 pp.

Kissell, F., N. Jayaraman, C. Taylor, and R. Jankowski. Reducing Dust at Longwall Shearers by Confining the Dust Cloud to the Face. BuMines TPR 111, 1981, 21 pp.

Kost, J. A., J. F. Colinet, and G. A. Shirey. Field Survey of Float Dust in Coal Mining Operations. BuMines OFR 17-82, October 1981, 162 pp.; NTIS, PB 82-172719.

Kost, J. A., and A. G. Mayton. 1979 Survey of Respirable Dust Control Research in Underground Coal Mines. BuMines OFR 137-80, May 1980, 145 pp.; NTIS, PB 81-130106.

Ku, H. H., and J. R. Rosenblatt. A Suggested Experimental Plan for the Determination of the Accuracy and Reliability of Coal Mine Dust Measurements. BuMines OFR 45-80, 1979, 48 pp.; NTIS, PB 80-173891.

Kutscher, B. S. Improved Light-Scattering Dust Monitor. BuMines OFR 127-80, January 1980, 99 pp.; NTIS, PB 81-128829.

Lambert, J. E., and P. Mighdoll. Feasibility of Control System Automation for a Drum Head Continuous Mining Machine. BuMines OFR 8-81, Aug. 10, 1979, 97 pp.; NTIS, PB 81-168361.

Lilienfeld, P. High Concentration Dust Monitor. BuMines OFR 159-81, June 1981, 76 pp.; NTIS, PB 82-139320.

——— Preliminary Design and Cost Estimate for Field

Worthy Simple Featured MMRDM Based on a Prototype Beta Attenuation/Filter Tape System Developed Under Contract Number H0166097. BuMines OFR 18-81, May 16, 1980, 96 pp.; NTIS, PB 81-166324.

Ludlow, J. E. Field Test of Deep Cutting Double Arm Shearer. BuMines OFR 118-81, March 1981, 159 pp.; NTIS, PB 81-246480.

Murphy, J. N. Dust Control Systems. Proc. 3d Ann. Min. Institute, University of Alabama, Apr. 15-17, 1980, 11 pp.

National Academy of Sciences. Measurement and Control of Respirable Dust in Mines. BuMines OFR 118-80, 1980, 405 pp.

Page, S. J. Correlation of the Fibrous Aerosol Monitor With the Optical Membrance Filter Count Technique. BuMines RI 8467, 1980, 21 pp.

_____. An Evaluation of Three Wet Dust Control Techniques for Face Drills. BuMines RI 8596, 1982, 13 pp.

_____. Evaluation of the Use of Foam for Dust Control on Face Drills and Crushers. BuMines RI 8595, 1982, 13 pp.

Page, S. J., C. W. Urban, and J. C. Volkwein. Effectiveness of Wet Cutter Bars in Reducing Salt Mine Dust. BuMines RI 8512, 1981, 10 pp.

Petty, A. V., Jr., and D. B. Nevin. Computer Program To Aid in Adjusting Particle Size Distribution. Am. Ceram. Soc. Bull., v. 60, No. 4, April 1981, pp. 506-507.

Pritts, I., and G. A. Bertone. Feasibility Study of Coal Dust Measurements by Light Reflectance Photometry. BuMines OFR 71-82, May 1981, 36 pp.; NTIS, PB 82-213927.

Rankin, R. L., and S. J. Rodgers. Study of Respirable Dust Outby the Working Face of a Coal Mine. BuMines OFR 98-81, Mar. 31, 1980, 180 pp.; NTIS, PB 81-236762.

Taylor, C. D., and R. A. Jankowski. How the Six Cleanest U.S. Longwalls Stay in Compliance. Min. Cong. J., v. 68, No. 5, May 1982, pp. 37-40.

Timko, R. J., K. L. Williams, and G. H. Schnakenberg, Jr. Laboratory Evaluation of the Du Pont P-2500 Automatic Flow-Controlled Personal Dust Sampling Pump. BuMines RI 8637, 1982, 18 pp.

Vinson, R. P., J. C. Volkwein, and E. D. Thimons. SF_6 Tracer Gas Tests of Bagging-Machine Hood Enclosures. BuMines RI 8527, 1981, 10 pp.

Volkwein, J. C., S. J. Page, and E. D. Thimons. Canopy-Air Curtain Dust Reductions on a Gathering-Arm Loader. BuMines RI 8603, 1982, 9 pp.

Volkwein, J. C., R. P. Vinson, and E. D. Thimons. Effectiveness of Three Water Spray Methods Used To Control Dust During Bagging. BuMines RI 8614, 1982, 9 pp.

_____. Effects of Humidity on Salt Mine Dust: A Preliminary Report. BuMines RI 8519, 1981, 9 pp.

Watts, W. F., Jr., R. L. Johnson, D. J. Donaven, and D. R. Parker. An Introduction to the Mine Inspection Data Analysis System (MIDAS). BuMines IC 8859, 1981, 41 pp.

Radiation Hazards

Bates, R. C. Time-Dependent ^{222}Rn Samples Loss From Small Samples. Health Phys., v. 39, November 1980, v. 39, pp. 799-801.

_____. Uranium Mine Ventilation Costs. BuMines IC 8855, 1981, 18 pp.

_____. Ventilation Cost Impact of Reduced Radon-Daughter Working Levels. Ch. 159 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 1066-1077.

Bates, R. C., and J. C. Edwards. The Effectiveness of Overpressure Ventilation: A Mathematical Study. Ch. 24 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 149-154.

_____. A Plan for Modeling Uranium Radon Daughter Concentrations. Ch. 38 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 256-259.

Borak, T. B., E. Franco, K. J. Schlager, J. A. Johnson, and R. F. Holub. Evaluation of Recent Developments in Radon Progeny Measurements. Ch. 66 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 419-425.

Breslin, J. A. Bureau of Mines Statement of Principles. Ch. 6 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 15-16.

Dodge, W. D., and V. B. Parr. Radon Daughter Dosimeter Tests in Active Uranium Mines. BuMines OFR 71-80, May 1980, 112 pp.; NTIS, PB 80-203599.

Droullard, R. F. Instrumentation for Measuring Uranium Miner Exposure to Radon Daughters. Ch. 51 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 332-338.

Durkin, J. The Error in Working-Level Hour. Calculations When the alpha-Energy From the Radon Daughters Is Not Discriminated. Health Phys., v. 41, No. 3, September 1981, pp. 477-481.

Edwards, J. C., and R. C. Bates. Theoretical Evaluation of Radon Emanation Under a Variety of Conditions. Health Phys., v. 39, August 1980, pp. 263-274.

Franklin, J. C. Control of Radiation Hazards in Underground Uranium Mines. Ch. 69 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 441-446.

Franklin, J. C., and D. M. Shaw. Airborne Radiation Warning System. Ch. 148 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 980-983.

Franklin, J. C., R. A. Washington, J. C. Kerkering, H. Montone, and R. Regan. Radon Emanation From Stopes Backfilled With Cemented Uranium Mill Tailings. BuMines RI 8664, 1982, 8 pp.

Holub, R. F. Two-Measurement Methods for Working-Level Determinations of Radon Daughters, A Theoretical Study. BuMines RI 8422, 1980, 47 pp.

Holub, R. F., P. J. Dallimore, and the Department of Physics and Geosciences, Western Australian Institute of Technology. Factors Affecting Radon Transport and the Concentration of Radon in Mines. Ch. 154 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 1022-1028.

Hopke, P. K., and J. J. Stukel. The Mechanism of Attachment of $^{218}Po(RaA)$ to Monodispersed Aerosols. BuMines OFR 14-81, Jan. 31, 1980, 155 pp.; NTIS, PB 81-166308.

Miller, R. I. Development of a Rapid Response Radon Monitor. BuMines OFR 62-80, Nov. 15, 1979, 69 pp.; NTIS, PB 80-183924.

Musulin, C. S., J. C. Franklin, and V. W. Thomas. Effect

of the Diurnal Cycle and Fan Shutdowns on Radon Concentration in an Experimental Uranium Mine. BuMines RI 8663, 1982, 13 pp.

Niewiadomski, G. E. The Role of the Bureau of Mines in Radiation Hazards Research. Ch. 18 in Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, ed. by M. Gomez. Pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 97-104.

Noise Control

Bartholomae, R. C., and J. G. Kovac. USBM Develops a Low-Noise Percussion Drill. Proc. Inter-Noise 80, Miami, Fla., Dec. 8-10, 1980, pp. 317-320.

Becker, R. S., and G. R. Anderson II. An Investigation of the Mechanics and Noise Associated With Coal Cutting. BuMines OFR 60-81, Feb. 15, 1980, 275 pp.; NTIS, PB 81-215394.

Bender, E. K., N. R. Dixon, M. N. Rubin, and R. C. Bartholomae. Noise Control of Jumbo-Mounted Percussion Drills. Noise Control Eng., v. 15, No. 3, November-December 1980, pp. 128-136.

Browning, J. A. Silencing the Flame Channelling Process. BuMines OFR 90-81, Feb. 27, 1980, 32 pp.; NTIS, PB 81-221996.

———. Silencing the Flame Channelling Process. Project Orion. Volume II. BuMines OFR 65-82, Dec. 30, 1981, 16 pp.; NTIS, PB 82-202664.

Daniel, J. H. Noise Abatement in Mining. Proc. 11th Ann. Inst. on Coal Mining Health, Safety and Research, Virginia Polytechnic Institute and State University, Blacksburg, Va., Aug. 26-28, 1980, pp. 137-147.

———. Noise Suppression in Taconite Plants. Pres. at AMC Ann. Conv., San Francisco, Calif., Sept. 21-24, 1980, pub. in Am. Min. Cong. J., v. 67, No. 3, March 1981, pp. 15-19.

Daniel, J. H., J. A. Burks, R. C. Bartholomae, R. Madden, and E. E. Ungar (comp.). Noise Control of Diesel-Powered Underground Mining Machines, 1979. BuMines IC 8837, 1981, 29 pp.

Dixon, N. R., M. N. Rubin, E. K. Bender, and R. C. Bartholomae. Noise Control of Jumbo-Mounted Percussion Drill. Proc. Inter-Noise 80, Miami, Fla., Dec. 8-10, 1980, pp. 491-494.

Ferrari, V., and A. Galaitsis. Integration of Quieting Technology Into New Mantrip Vehicles. BuMines OFR 62-82, October 1981, 164 pp.; NTIS, PB 82-203241.

Fuchs, E. P. The Effects of Underground Environment and Loading Conditions on Noise Levels of Coal Mining Equipment. Final Report—Volume I. BuMines OFR 97(1)-80, March 1979, 230 pp.; NTIS, PB 80-227606.

———. The Effects of Underground Environment and Loading Conditions on Noise Levels of Coal Mining Equipment. Final Report—Volume II. BuMines OFR 97(2)-80, March 1979, 138 pp.; NTIS, PB 80-227614.

Galaitsis, A. G., and D. Andersen. Noise Control of a Mine Operated Rail Personnel Carrier. Volume II. Underground Evaluation. BuMines OFR 155-81, July 1980, 35 pp.; NTIS, PB 82-137019.

Galaitsis, A., R. Madden, and D. Anderson. Noise Reduction of Chain Conveyors. BuMines OFR 133-80, December 1979, 144 pp.; NTIS, PB 81-130833.

Galaitsis, A., R. Madden, A. Reams, R. Bartholomae, and T. Bobick. Noise Reduction of Chain Conveyors. Proc. Inter-Noise 80, Miami, Fla., Dec. 8-10, 1980, pp. 169-172.

George D. L., and N. J. Matteo. Development of Noise Control Technology for Pneumatic Jumbo Drills. BuMines OFR 100-81, November 1980, 61 pp.; NTIS, PB 81-237414.

Kovac, J. G., R. C. Bartholomae, and G. R. Bockosh. Bulldozer Noise Control. Proc. Inter-Noise 80, Miami, Fla., Dec. 8-10, 1980, pp. 457-460.

Markel, M. V. Field Evaluation of Resiliently Clad Screen Decks. BuMines OFR 67-82, March 1981, 37 pp.; NTIS, PB 82-204876.

Morgan, J. A. Taconite Crusher Noise Reduction—Study of Acoustical Enclosure for Symons 7-Foot, Standard Head, Extra-Heavy Duty Cone Crusher. BuMines OFR 64-82, September 1980, 40 pp.; NTIS, PB 82-202649.

Redmond, G. W., K. C. Stewart, E. J. Burgi, and R. C. Bartholomae. Comparison of Earmuff Attenuation as Measured by Psychophysical and Physical Methods. Proc. Inter-Noise 80, Miami, Fla., Dec. 8-10, 1980, pp. 659-662.

Staiano, M. A., W. Benson, and T. A. Gates. Technology for Environmental Noise Control in Surface Mines. Final Report. BuMines OFR 51-82, August 1981, 122 pp.

Visnapuu, A., B. A. Betts, and L. A. Neumeier. Influence of Graphite Morphology on the Damping Properties of Selected Cast Iron Structures. 37th Electric Furnace Conf. Proc., AIME, Detroit, Mich., Dec. 4-7, 1979; July 1980, pp 304-306.

Industrial Hygiene

Burough, I. G. Development of a Personal CO_2 Detector and a CH_4 Detector. BuMines OFR 15-81, August 1979, 125 pp.; NTIS, PB 81-163982.

Derby, G. K. Reduction of Airborne Contaminants From Welding Exhaust at Surface Mines. BuMines IC 8868, 1982, 11 pp.

Eccleston, B. H., D. E. Seizinger, and J. M. Clingenpell. Diesel Exhaust Emissions From Engines for Use in Underground Mines. BuMines OFR 105-82, April 1981, 42 pp.

Freedman, R. W., and F. A. Sharp. Determination of Sulfates in Diesel Exhaust. BuMines RI 8683, 1982, 7 pp.

Greuer, R. E. Real-Time Precalculation of the Distribution of Combustion Products and Other Contaminants in the Ventilation System of Mines. BuMines OFR 22-82, Mar. 15, 1981, 263 pp.; NTIS, PB 82-183104.

Holland, W. D. Determination of Breathing Zone Concentrations of Contaminants From Emissions From Diesel Powered Vehicles in Underground Mines. BuMines OFR 24-80, 1978, 127 pp.; NTIS, PB 80-150766.

———. Surveying Inhalation Contaminants in Above-Ground Metal and Nonmetal Mining and Processing Work Areas. Instructor's Teaching Guide (For Company Safety Officers). BuMines OFR 9(3)-80, 1977, 81 pp.; NTIS, PB 80-142946.

———. Surveying Inhalation Contaminants in Above-Ground Metal and Nonmetal Mining and Processing Work Areas. Instructor's Teaching Guide (For MSHA Inspectors). BuMines OFR 9(2)-80, 1977, 66 pp.; NTIS, PB 80-142938.

Johnson, J. H., D. H. Carlson, and E. O. Reinbold. The Application of Advanced Mine Air Monitoring Techniques to Mines Using Diesel Powered Equipment. BuMines OFR 76-80, July 31, 1979, 191 pp.; NTIS, PB 80-207541.

Johnson, J. H., D. H. Carlson, E. O. Reinbold, and M. D. Osborne. Monitoring of Mine Air Diesel Pollutants: Tailpipe Emissions Measurement Apparatus, Detector Tube Interferences, and Exhaust and Ventilation System Control. BuMines OFR 3-82, July 31, 1980, 267 pp.; NTIS, PB 82-148388.

Kosek, J., and S. Bruckenstein. Electrochemical Gas

Sensors for Mine Atmospheres: Portable Detectors for Carbon Monoxide and for Nitric Oxide/Nitrogen Dioxide Mixtures. BuMines OFR 58-81, February 1979, 212 pp.; NTIS, PB 81-214934.

Kosek, J. A., and A. H. Gruber. Development of Improved Detection Instruments for Toxic Gas Contaminants in Mining Atmospheres. BuMines OFR 139-81, February 1981, 115 pp.; NTIS, PB 82-129578.

Kosek, J. A., A. B. LaConti, A. Goldstein, G. Schnakenberg, and E. Chilton. Development of Fuel Cell Gas Detection Instruments for Use in a Mine Atmosphere. BuMines OFR 164-81, Mar. 23, 1979, 131 pp.; NTIS, PB 82-137316.

LFE Corp. Handbook for Surveys of Inhalation Contaminants in Above-Ground Metal and Nonmetal Mining and Processing Work Areas. BuMines OFR 9(1)-80, 1977, 87 pp.; NTIS, PB 80-143969.

Little (Arthur D., Inc.). Development of a Through-the-Earth Monitor System. BuMines OFR 99-81, December 1980, 31 pp.; NTIS, PB 81-237646.

McClatchie, E. A., and I. G. Burough. Development of a Portable Gas Analyzer for In-Mine Personnel Monitoring. BuMines OFR 108-81, Aug. 15, 1980, 129 pp.; NTIS, PB 81-236770.

McCoy, J. F., A. Whillier, K. S. Heller, and E. D. Thimons, Development of an In-Line Water Spray Cooler. J. Mine. Vent. Soc. S. Afr., v. 35, No. 1, January 1982, pp. 1-6.

MDA Scientific, Inc. Development of a Personal Monitoring Field Kit for NO_2 and NO. BuMines OFR 105-81, Jan. 30, 1981, 22 pp.; NTIS, PB 81-237406.

Menzies, K. T., P. L. Levins, M. G. Broome, and M. H. Fanucci. State-of-the-Art of Sampling and Analysis for Diesel Exhaust Contaminants. BuMines OFR 63-80, 1979, 174 pp.; NTIS, PB 80-183353.

Newman, J. S. Procedures for the Performance Evaluation of Gas Detection Devices Including Preliminary Test Methods. BuMines OFR 38-81, May 23, 1980, 251 pp.; NTIS, PB 81-194961.

O'Neal, G. B., J. O. Storment, and R. W. Waytulonis. Emulsified Fuel Effects on Performance and Emissions of a Prechamber Diesel Engine for Underground Mines. Pres. at SAE Off-Highway Vehicle Meeting and Expo, Milwaukee, Wis., Sept. 14-16, 1981, SAE Tech. Paper 810954, 16 pp.

Palmes, E. D., and C. Tomczyk. Personal Samplers for CO, NO, and NO_2 in Air. BuMines OFR 137-81, January 1980, 36 pp.; NTIS, PB 82-123597.

Ramani, R. V., and G. W. Kenzy. Evaluation of Diesel Equipment Deployment in Underground Coal Mines. Volume III: Analysis of Diesel Deployment Schemes. BuMines OFR 128-81, Dec. 31, 1978, 202 pp.; NTIS, PB 82-122151.

Ryan, T. W., and R. W. Waytulonis. Effects of Fuel Properties and Composition on Diesel Exhaust Emission—A Review. Pres. at SAE Off-Highway Vehicle Meeting and Expo, Milwaukee, Wis., Sept. 14-16, 1981, SAE Tech. Paper 810953, 16 pp.

Thimons, E. D., and J. H. Daniel. The Water Spray Cooler—An Update. BuMines TPR 114, 1981, 9 pp.

Thimons, E. D., and R. N. Torbin. Thermal Energy Recovery for Deep Mines. Pres. at 1st Mine Ventilation Symp., Univ. Ala., Tuscaloosa, Ala., Mar. 29-31, 1982; Eng. and Min. J., v. 183, No. 5, May 1982, pp. 98-99.

Waytulonis, R. W. State Regulations Pertaining to the Use of Internal Combustion Engines Underground. BuMines IC 8845, 1981, 76 pp.

Waytulonis, R. W., S. D. Smith, and L. C. Mejia. Failure Analysis of Diesel Exhaust-Gas Water Scrubbers. BuMines RI 8682, 1982, 16 pp.

Ventilation

Dorman, K. R., and J. [illegible]. Constructing Ventilation Bulkheads With Sh[illegible] Panel. BuMines RI 8491, 1980, 24 pp.

Greuer, R. E. Precalculation of the Effect of Fires on Ventilation Systems of Mines. Volume I. BuMines OFR 8(1)-81, June 27, 1979, 85 pp.

———. Precalculation of the Effect of Fires on Ventilation Systems of Mines. Volume II, Figures and Tables. BuMines OFR 81(2)-81, June 27, 1979, 182 pp.

———. Precalculation of the Effect of Fires on Ventilation Systems of Mines. Volume III, Figures and Tables. BuMines OFR 81(3)-81, June 27, 1979, 215 pp.

Lewtas, T. A. Assessment of Induction Fan Effectiveness. BuMines OFR 81-82, March 1980, 62 pp.; NTIS, PB 82-235987.

Purtell, L. P. Low Velocity Performance of Anemometers. BuMines OFR 26-80, 1979, 170 pp.; NTIS, PB 80-158801.

Thimons, E. D., and F. N. Kissell. Bureau of Mines New Stopping Designs—An Update. Min. Cong. J., v. 67, No. 7, July 1981, pp. 1-4.

Timko, R. J., M. D. Marshall, and J. C. King. Brushes Lessen Stopping Leaks. Coal Age, v. 87, No. 4, April 1982, pp. 108-114.

Vinson, R. P., F. N. Kissell, J. C. LaScola, and E. D. Thimons. Face Ventilation Measurement With Sulfur Hexafluoride (SF_6). BuMines RI 8473, 1980, 16 pp.

Fire and Explosion Prevention

Baker, R. M., J. Nagy, L. B. McDonald, and J. Wishmyer. An Annotated Bibliography of Metal and Nonmetal Mine Fire Reports. Final Report, Volume I. BuMines OFR 68(1)-81, Dec. 5, 1980, 64 pp.; NTIS, PB 81-223729.

———. An Annotated Bibliography of Metal and Nonmetal Mine Fire Reports. Volume II. BuMines OFR 68(2)-81, Dec. 5, 1980, 284 pp.; NTIS, PB 81-223737.

———. An Annotated Bibliography of Metal and Nonmetal Mine Fire Reports. Final Report, Appendix. BuMines OFR 68(3)-81, Dec. 5, 1980, 390 pp.; NTIS, PB 81-223745.

———. An Annotated Bibliography of Metal and Nonmetal Mine Fire Reports. Final Report, Volumes I, II, and Appendix. BuMines OFR 68(1)—(3)-81, Dec. 5, 1980, 738 pp.; NTIS, PB 81-223711.

Bartholomae, R. C., G. W. Redmond, and R. S. Norman. Flammability Evaluation of Noise Control Products for Use in Underground Coal Mines. Proc. Inter-Noise 80, Miami, Fla., Dec. 8-10, 1980, pp. 637-640.

Baum, B., and W. Holley. Combined Fire/Rot Retardant Treatment for Wood Mine Timber. BuMines OFR 20-81, October 1978, 105 pp.; NTIS, PB 81-166381.

Bossart, C. J. Design of a Portable Gas Analyzer for Monitoring During Mine Fires. BuMines OFR 59-82, May 10, 1978, 54 pp.; NTIS, PB 82-202748.

Cashdollar, K. L., and M. Hertzberg. Infrared Pyrometers for Measuring Dust Explosion Temperatures. Modern Utilization of Infrared Technol. VI, SPIE, v. 253, 1980, pp. 254-260.

Cashdollar, K. L., I. Liebman, and R. S. Conti. Three Bureau of Mines Optical Dust Probes. BuMines RI 8542, 1981, 26 pp.

Cashdollar, K. L., J. M. Singer, C. K. Lee, and C. D. Litton. Smoke Characteristics of Coal-Lined Tunnel Fires. Fire and Mater., v. 5, No. 2, 1981, pp. 47-51.

Chi, D. N. H., and H. E. Perlee. Fire-Fighting Mini. Datamation Mag., September 1980, pp. 217-220.

Christos, T., and D. R. Forshey. Thermal Degradation Products of Solvents and Hydraulic Fluids Used in Mining. BuMines RI 8517, 1981, 14 pp.

Conti, R. S., K. L. Cashdollar, and I. Liebman. Improved Optical Probe for Monitoring Dust Explosions. Rev. Sci. Inst., v. 53, No. 3, 1982, pp. 311-313.

Cory, T. S. Methane Telemetry System for Continuous Miners. BuMines OFR 9-82, June 22, 1979, 96 pp.; NTIS, PB 82-163940.

Courtney, W. G. Preventing Frictional Ignitions. Coal Min. & Proc. J., v. 8, No. 1, January 1981, pp. 48-58.

Dieckmann, J. T., and S. K. Ruggieri. Design, Fabrication and Demonstration of an Inert Gas Generator. BuMines OFR 12-80, 1979, 106 pp.; NTIS, PB 80-145881.

Driscoll, T. J., D. R. Flinn, and W. C. Lederer. Application of a Photodiode Array Optical Spectrometer to the Study of the Incendivity of Light Alloys Impacting on Rusted Steel. BuMines RI 8685, 1982, 17 pp.

Edwards, J. C., and H. E. Perlee. Superheated Drop Vaporization: Halon 1301. BuMines RI 8658, 1982, 19 pp.

Fitch, E. C., and J. S. Campbell. Fire-Resistant Hydraulic Fluid Safety. BuMines OFR 33-80, 1979, 51 pp.; NTIS, PB 80-159486.

Hertzberg, M. The Theory of Flammability Limits. Conductive-Convective Wall Losses and Thermal Quenching. BuMines RI 8469, 1980, 25 pp.

———. The Theory of Flammability Limits. Radiative Losses and Selective Diffusional Demixing. BuMines RI 8607, 1982, 38 pp.

Hertzberg, M., K. L. Cashdollar, and C. P. Lazzara. The Limits of Flammability of Pulverized Coals and Other Dusts. Proc. 18th Internat. Symp. on Combustion, Ontario, Canada, Aug. 9, 1980. The Combustion Institute, 1981, pp. 717-729.

Holley, W. H. Continued Research on Combined Fire/Rot Retardant Treatment for Wood Mine Timbers. BuMines OFR 115-81, October 1980, 81 pp.; NTIS, PB 81-244493.

Kansa, E. J. An Algorithm for Multidimensional Combusting Flow Problems. J. Comput. Phys., v. 42, No. 1, July 1981, pp. 152-194.

Kansa, E. J., and H. E. Perlee. A Transient Dust-Flame Model: Application to Coal-Dust Flames. Combust. Flame, v. 38, 1980, pp. 17-36.

Kohout, F. C., E. N. Ladov, and D. A. Law. Improved Fire Safety of Coal Mine Hydraulic Systems. BuMines OFR 19-81, March 1979, 155 pp.; NTIS, PB 81-166852.

Kubala, T. A., F. J. Perzak, and E. L. Litchfield. Electric Ignition of Lycopodium Powder in a Modified Hartmann Apparatus. BuMines RI 8600, 1981, 9 pp.

Kuchta, J. M., A. L. Furno, L. E. Dalverny, M. J. Sapko, and C. D. Litton. Diagnostics of Sealed Coal Mine Fires. BuMines RI 8625, 1982, 25 pp.

Kuchta, J. M., V. R. Rowe, and D. S. Burgess. Spontaneous Combustion Susceptibility of U.S. Coals. BuMines RI 8474, 1980, 37 pp.

Kuchta, J. M., M. J. Sapko, F. J. Perzak, and K. E. Mura. Improved Fire Resistance Test Method for Belt Materials. Fire Technol., v. 17, No. 2, May 1981, pp. 120-130.

Lease, W. D. Development of an Automatic Fire Protection System for Surface Vehicles. Final Report—Volume I. BuMines OFR 73-82, Jan. 31, 1981, 74 pp.; NTIS, PB 82-215765.

Litchfield, E. L., T. A. Kubala, T. Schellinger, F. J. Perzak, and D. Burgess. Practical Ignition Problems Related to Intrinsic Safety in Mine Equipment. Four Short-Term Studies. BuMines RI 8464, 1980, 18 pp.

Litton, C. D., M. Hertzberg, and A. L. Furno. Fire Detection Systems in Conveyor Belt Entangleways. BuMines RI 8632, 1982, 26 pp.

Litton, C. D., M. Hertzberg, A. L. Furno, and J. M. Kuchta. Monitoring Submicrometer Particles in Sealed Fire Areas. BuMines RI 8586, 1981, 20 pp.

Marshall, M. D., E. D. Thimons, D. W. Kneebone, and S. Gross. Canister Concept Provides Early Fire Warning in Mines. Min. Cong. J., v. 68, No. 4, April 1982, pp. 64-69.

McDonald, L. B., and R. M. Baker. An Annotated Bibliography of Coal Mine Fire Reports. Volume I. BuMines OFR 7(1)-80, 1979, 93 pp.; NTIS, PB 80-140205.

———. An Annotated Bibliography of Coal Mine Fire Reports. Volume II. BuMines OFR 7(2)-80, 1979, 400 pp.; NTIS, PB 80-140213.

———. An Annotated Bibliography of Coal Mine Fire Reports. Appendix. BuMines OFR 7(3)-80, 1979, 654 pp.; NTIS, PB 80-140221.

———. An Annotated Bibliography of Coal Mine Fire Reports. Volumes I Through III. BuMines OFR 7(1)—(3)-80 (set), 1979, 1147 pp.; NTIS, PB 80-140197 (set).

Miron, Y. Thermal Decomposition of Monomethylamine Nitrate. J. Hazardous Mater., Elsevier Scientific Publishing Co., Amsterdam, the Netherlands, v. 3, 1980, pp. 301-321.

Muldoon, T. L., T. Lazetas, and T. E. Gore. Upgrade Stench Fire Warning System—System Development and Prototype Tests. BuMines OFR 136-81, April 1981, 142 pp.; NTIS, PB 82-122128.

Norman, R. S., R. A. Hedeen, J. W. Kopec, and T. E. Waterman. Flammability Evaluation of Noise Control Products for Use in Underground Coal Mines. BuMines OFR 92-80, June 1979, 95 pp.; NTIS, PB 81-101990.

Paciorek, K. L., R. H. Kratzer, J. H. Nakahara, and D. H. Harris. Determination of the Products of the Oxidative Thermal Degradation of Variously Treated Woods and Mine Materials. BuMines OFR 4-82, July 1980, 182 pp.; NTIS, PB 82-146275.

Papp, J. F., C. P. Lazzara, and J. C. Biordi. Structure Study of a CF_2BR_2-Inhibited Methane Flame. Effect of CF_2BR_2 on Composition, Net Reaction Rates, and Rate Coefficients. BuMines RI 8551, 1981, 32 pp.

Pomroy, W. H., and K. L. Bickel. Automatic Fire Protection Systems for Surface Mining Equipment. BuMines IC 8832, 1980, 38 pp.

Ruggieri, S. K., and J. T. Dieckmann. Design, Fabrication and Demonstration of an Inert Gas Generator. Volume II. Operations and Maintenance Manual. BuMines OFR 72-80, January 1980, 150 pp.; NTIS, PB 80-207368.

Sapko, M. J., K. E. Mura, A. L. Furno, and J. M. Kuchta. Fire Resistance Test Method for Conveyor Belts. BuMines RI 8521, 1981, 27 pp.

Scott, L. W., and J. G. Dolgos. Electric Arcing at High Voltage During Methane-Air Explosions Inside Explosion-Proof Enclosures. BuMines TPR 115, 1982, 9 pp.

Smoot, L. D., and M. D. Horton. Exploratory Studies of Flame and Explosion Quenching. BuMines OFR 104-82, Aug. 31, 1979, 317 pp.

Stevens, R. B. Improved Spontaneous Combustion Protection for Underground Metal Mines. BuMines OFR 79-80, November 1979, 262 pp.; NTIS, PB 80-210461.

Stott, J. B. The Spontaneous Heating of Coal and the Role of Moisture Transfer. BuMines OFR 113-81, July 1980, 78 pp.

Treuhaft, M. B., and B. C. Dial. Study of Air Compressor

Hazards to Underground and Surface Mines. BuMines OFR 132-81, January 1981, 93 pp.; NTIS, PB 82-105164.

U.S. Bureau of Mines, Staff. Underground Metal and Nonmetal Mine Fire Protection. Proceedings: Bureau of Mines Technology Transfer Seminars, Denver, Colo., Nov. 3, 1981, and St. Louis, Mo., Nov. 6, 1981. BuMines IC 8865, 1981, 150 pp.

Welsh, J. H. Computerized, Remote Monitoring Systems for Underground Coal Mines. Fires and Explosive Atmospheres. BuMines IC 8875, 1982, 9 pp.

Whiting, B. A., L. D. Smoot, and V. J. Crandall. Exploratory Studies of Flame and Explosion Quenching. Volume II. User's Manual for Flame Propagation Code for Premixed Laminar Heterogeneous Systems. BuMines OFR 11-81, Aug. 31, 1979, 296 pp.; NTIS, PB 81-183949.

Zborovsky, Z. Intrinsically Safe Supporting Research. BuMines OFR 7-81, April 1980, 148 pp.; NTIS PB 81-179384.

Methane Control

Cervik, J. Methane Control on Longwall—European and U.S. Practices. Pres. at Soc. Min. Eng., AIME, Ann. Meeting, New Orleans, La., Feb. 18-22, 1979; Ch. 9 in Longwall-Shortwall Mining, State of the Art, 1981, pp. 75-80.

Diamond, W. P., and J. R. Levine. Direct Method Determination of the Gas Content of Coal: Procedures and Results. BuMines RI 8515, 1981, 36 pp.

Diamond, W. P., and D. C. Oyler. Drilling Long Horizontal Coalbed Methane Drainage Holes From a Directional Surface Borehole. Pres. at SPE/DOE Symp. on Unconventional Gas Recovery, Pittsburgh, Pa., May 18-21, 1980, SPE Preprint 8968, pp. 341-346.

Finfinger, G. L., and J. Cervik. Review of Horizontal Drilling Technology for Methane Drainage From U.S. Coalbeds. BuMines IC 8829, 1980, 20 pp.

Finfinger, G. L., L. J. Prosser, Jr., and J. Cervik. Influence of Coalbed Characteristics and Geology on Methane Drainage. Pres. at SPE/DOE Symp. on Unconventional Gas Recovery, Pittsburgh, Pa., May 18-21, 1980, SPE Preprint 8964, pp. 319-324.

Goodman, T. W., J. Cervik, and G. N. Aul. Degasification Study From an Air Shaft in the Beckley Coalbed. BuMines RI 8675, 1982, 19 pp.

Iannacchione, A. T., and D. W. Houseknecht. Methane Production Potential From Hartshorne Coal Beds in Deep Parts of Pittsburgh, Coal, and Hughes Counties, Oklahoma. Am. Assoc. Pet. Geol. Bull., v. 65, No. 8, August 1981, pp. 1499-1500.

Irani, M. C., F. F. Kapsch, P. W. Jeran, and S. J. Pepperney. A Fail-Safe Control System for a Mine Methane Pipeline. BuMines RI 8424, 1980, 11 pp.

Lambert, S. W., M. A. Trevits, and P. F. Steidl. Vertical Borehole Design and Completion Practices To Remove Methane Gas From Mineable Coalbeds. DOE IR DOE-CMTC-TR-80-2, 1980, 163 pp.

LaScola, J. C., J. E. Matta, and F. N. Kissell. Assessing the Methane Hazard of Gassy Coals in Storage Silos. BuMines RI 8525, 1981, 9 pp.

Lee, C. K., R. F. Chaiken, J. M. Singer, and M. E. Harris. Behavior of Wood Fires in Model Tunnels Under Forced Ventilation Flow. Tests With Untreated Wood. BuMines RI 8450, 1980, 58 pp.

Lunsden, A., and R. Talbot. Study to Develop Data for Review of Metal and Non-Metal Mine Methane Hazard Classification. BuMines OFR 82-82, April 1982, 153 pp.

Maksimovic, S. D., and F. N. Kissell. Three Coal Mine Gob Degasification Studies Using Surface Boreholes and a Bleeder System. BuMines RI 8459, 1980, 10 pp.

McLaughlin, D. J. Millhiser, and B. Bonarek. Cableless Electronic Surveying Systems for Horizontal Holes. BuMines OFR 14-82, March 1981, 235 pp.; NTIS, PB 82-164526.

Oyler, D. C., and W. P. Diamond. Drilling a Horizontal Coalbed Methane Drainage System From a Directional Surface Borehole. BuMines RI 8640, 1982, 50 pp.

Perry, J. H., L. J. Prosser, Jr., and J. Cervik. Degasification of the Mary Lee Coalbed, Brookwood, Ala. BuMines RI 8669, 1982, 13 pp.

———. Methane Drainage From the Mary Lee Coalbed, Alabama, Using Horizontal Drilling Techniques. Pres. at SPE/DOE Symp. on Unconventional Gas Recovery, Pittsburgh, Pa., May 18-21, 1980, SPE Preprint 8967, pp. 335-340.

Prosser, L. J., Jr., G. L. Finfinger, and J. Cervik. Methane Draining Study Using an Underground Pipeline, Marianna Mine 58. BuMines RI 8577, 1981, 29 pp.

Schatzel, S. J., G. L. Finfinger, and J. Cervik. Underground Gob Gas Drainage During Longwall Mining. BuMines RI 8644, 1982, 14 pp.

Skow, M. L., A. G. Kim, and M. Dusl. Creating a Safer Environment in U.S. Coal Mines. The Bureau of Mines Methane Control Program, 1964-79. BuMines Spec. Pub. 5-81, 1980, 50 pp.

Steidl, P. F., M. A. Trevits, and W. P. Diamond. Completion Techniques and Production Data From Vertical Methane Drainage Boreholes, Jawbone Coalbed, Dickenson County, Va. Pres. at SPE/DOE Symp. on Unconventional Gas Recovery, Pittsburgh, Pa., May 18-21, 1980, SPE Preprint 8965, pp. 325-328.

Trevits, M. A., W. L. Richards, and H. A. Von Schonfeldt. Determining the Feasibility of Using Vertical Boreholes To Drain Gas From the Pocahontas No. 3 Coalbed, Buchanan County, Va. Pres. at SPE/DOE Symp. on Unconventional Gas Recovery, Pa., May 18-21, 1980, SPE Preprint 8966, pp. 329-334.

Explosives

Becker, K. R., and J. E. Hay. Effect of Direct-Current Firing Levels on Detonator Delay Times. BuMines RI 8613, 1982, 13 pp.

Coulson, J. R., and L. T. Southall, II. Considerations for the Certification of Blasters. BuMines OFR 59-81, February 1980, 79 pp.; NTIS, PB 81-214116.

Kendorski, F. S., and M. F. Dunn. Safety and Cost Benefits From Improved Highwall Blasting Practice. BuMines OFR 54-82, February 1981, 171 pp.; NTIS, PB 82-205491.

Mainiero, R. J., and J. E. Hay. Evaluation of a Sheathed Permissible Explosive Charge for Open Shooting in Flammable Atmospheres. BuMines TPR 118, 1982, 9 pp.

Roth, J. A Model for the Determination of Flyrock Range as a Function of Shot Conditions. BuMines OFR 77-81, Apr. 16, 1979, 97 pp.; NTIS, PB 81-222358.

Roth, J., K. C. Britton, R. W. Campbell, and W. R. Kettler. Evaluation of Surface Mining Blasting Procedures. BuMines OFR 18-80, June 6, 1978, 162 pp.; NTIS, PB 80-148653.

Scott, J. H., K. R. Becker, and J. E. Hay. Evaluation of REO Model BT 300 C-D Blasting Machine Tester. BuMines RI 8606, 1982, 15 pp.

Sengupta, D., G. French, M. Heydari, and K. Hanna. The Impact of Eliminating Safety Fuse From Metal/Nonmetal

Mines. BuMines OFR 61-81, August 1980, 211 pp.; NTIS, PB 81-215386.

Postdisaster Survival and Rescue

Berry, D. R., and D. W. Mitchell. Recommended Guidelines for Oxygen Self-Rescuers—Volume I, Underground Coal Mining. BuMines OFR 86(1)-81, June 1981, 52 pp.; NTIS, PB 81-225872.

———. Recommended Guidelines for Oxygen Self-Rescuers—Volume II, Appendices. BuMines OFR 86(2)-81, June 1981, 265 pp.; NTIS, PB 81-225880.

Burse, R. L., and L. D. Strong. Low Temperature Tests of Rescue Breathing Apparatus. BuMines OFR 16-82, July 1981, 113 pp.; NTIS, PB 82-172727.

Davies, C. L., and E. H. Izen. Infrared Imaging Borehole Probe (Infrared Borehole Imaging Probe). BuMines OFR 125-81, April 1980, 89 pp.

Durkin, J., and R. J. Greenfield. Evaluation of the Seismic System for Locating Trapped Miners. BuMines RI 8567, 1981, 55 pp.

Dyson, T. F. Automatic Trapped Miner Seismic Signal Detection and Analysis System. BuMines OFR 10-82, May 21, 1981, 72 pp.; NTIS, PB 82-161936.

Kehrman, R. F., A. J. Farstad, and D. Kalvels. Reliability and Effectiveness Analysis of the USBM Electromagnetic Location System for Coal Mines, Final Report. BuMines OFR 47-82, Dec. 1, 1978, 153 pp.; NTIS, PB 82-201385.

Kyriazi, N. Effects of CO_2-Absorbent Canister Design on LiOH Efficiency in Closed-Circuit Breathing Apparatus. BuMines RI 8513, 1981, 13 pp.

Marshall, M. D. Development of a Manually Operated Rescue Team Vehicle. BuMines OFR 34-81, Feb. 2, 1978, 183 pp.; NTIS, PB 81-194482.

National Academy of Sciences, Commission on Sociotechnical Systems. Underground Mine Disaster Survival and Rescue: An Evaluation of Research Accomplishments and Needs. BuMines OFR 44-82, 1981, 122 pp.

Raab, F. H., and P. K. Hansen. Electromagnetic Retransmission System for Locating Trapped Mine Workers. BuMines OFR 48-81, February 1980, 268 pp.; NTIS, PB 81-215329.

Ristenbatt, M. P., and E. K. Holland-Moritz. Evaluation and Demonstration of a New Post-Disaster EM Communication Technique for Mines. BuMines OFR 151-81, February 1981, 101 pp.; NTIS, PB 82-143181.

Sanders, M. S., T. G. Bobick, and J. W. Stengel. Personal Equipment Development for Underground Use. Pres. at Intersociety Conf. on Environmental Systems, San Francisco, Calif., July 13-15, 1981, ASME Preprint 81-ENAS-48, 6 pp.

Sparks, A. W., R. L. Stein, and J. W. Stengel. A Breathing Metabolic Simulator for Testing Respiratory Protective Equipment. BuMines RI 8496, 1980, 18 pp.

Stengel, J. W., N. Kyriazi, and S. L. Benz. Laboratory Testing of Chemical Oxygen Self-Rescuers for Ruggedness and Reliability. BuMines RI 8657, 1982, 21 pp.

Watson, R. W., W. J. Doyak, and A. L. Furno. Evaluation of the Safety of One-Hour Chemical Self Rescuers. BuMines OFR 123-80, November 1980, 184 pp.

Systems Engineering

Clark, J., and J. H. Caldon. An Assessment of Thin Seam Mining System Technology. BuMines OFR 102-81, July 1980, 379 pp.; NTIS, PB 81-237455.

Davis, R. P., G. R. Brown, and W. J. Douglas. Benefit-Cost Analysis of Health and Safety Research and Development Projects in Coal, Metal and Non-Metal Mining. BuMines OFR 78-82, May 1981, 108 pp.; NTIS, PB 82-218660.

Doerfler, T. E. Statistical Studies—Metal/Nonmetal Mine Fatality Studies. BuMines OFR 13-81, July 1980, 48 pp.; NTIS, PB 81-167561.

McDonald, L. B., and W. H. Pomroy. A Statistical Analysis of Coal Mine Fire Incidents in the United States From 1950 to 1977. BuMines IC 8830, 1980, 42 pp.

Patterson, W. N., L. Travis, and L. Owens. Survey of Attractive Energy Storage and Power Averaging Concepts Applicable to Mining Machines. BuMines OFR 53-81, July 31, 1980, 154 pp.; NTIS, PB 81-217002.

Short, J., J. Harris, J. Waldo, and S. Barber. A Study to Determine the Manpower and Training Needs of the Coal Mining Industry. BuMines OFR 14-80, 1979, 145 pp.; NTIS, PB 80-164472.

Short, J., J. Harris, J. Waldo, and S. Barber. A Study To Determine the Manpower and Training Needs of the Coal Mining Industry. BuMines OFR 14-80, 1979, 145 pp.; NTIS, PB 80-164472.

U.S. Bureau of Mines, Staff—Division of Minerals Health and Safety Technology. Minerals Health and Safety In-House and Contract Research, Development, and Demonstration in Fiscal Year 1982. BuMines IC 8872, 1982, 48 pp.

Ground Control

Agapito, J. F. T., S. J. Mitchell, M. P. Hardy, and W. N. Hoskins. Determination of In Situ Horizontal Rock Stress on Both a Mine-Wide and District-Wide Basis. BuMines OFR 143-80, Mar. 1, 1980, 175 pp.; NTIS, PB 81-139735.

Agbabian Associates. The Three-Dimensional Structural Analysis of Double-Entry and Single-Entry Coal Mines. Final Report. Volumes I Through III. BuMines OFR 16(1)—(3)-80 (set), 1978, 706 pp.; NTIS, PB 80-150 337 (set).

Alison, D. R., E. T. Ohlsson, and K. V. Whitney. Geologic and Engineering Data Acquisition for Underground Coal Mine Ground Control. BuMines OFR 89-80, January 1980, 100 pp.; NTIS, PB 80-219272.

Anderson, G. L., and T. W. Smelser. Development Testing and Analysis of Steel-Fiber-Reinforced Concrete Mine Support Members. Support System Design and Results of Laboratory Investigation and Full-Scale Testing. BuMines RI 8412, 1980, 38 pp.

Balanchandra, M. B. The Three-Dimensional Structural Analysis of Double-Entry and Single-Entry Coal Mines. Final Report. Volume I. Three-Dimensional Finite Element Analysis of Crosscut and Entry Intersections of a Double-Entry Coal Mine. BuMines OFR 16(1)-80, 1976, 137 pp.; NTIS, PB 80-150345.

Barla, G., and S. H. Boshkov. A Study of the Behavior of Underground Openings During Block Caving Operations. BuMines OFR 74-81, June 1979, 400 pp.

Bathe, K. J. ADINA/BM—A General Computer Program for Nonlinear Analysis of Mine Structures. BuMines OFR 19-82, February 1978, 415 pp.; NTIS, PB 82-180993.

Bauer, E. R., and G. J. Chekan. Convergence Measurements for Squeeze Monitoring: Instrumentation and Results. BuMines TPR 113, 1981, 9 pp.

Beus, M. J., and S. S. M. Chan. Shaft Design in the Coeur d'Alene Mining District, Idaho—Results on In Situ Stress and Physical Property Measurements. BuMines RI 8435, 1980, 39 pp.

Blake, W. Preconditioning an Entire Stope Block for

Rock Burst Control. BuMines OFR 51-81, May 1980, 32 pp.; NTIS, PB 81-214983.

———. Wallrock Reactions to Mining Beyond a Preconditioned Zone at the Star Mine, Burke, Idaho. BuMines OFR 52-81, April 1980, 45 pp.; NTIS, PB 81-214355.

Brandt, H. W. Field Test of Chemical Injection for Stabilizing Coal Mine Roof. BuMines OFR 48-80, December 1977, 57 pp.

Burdick, R. D., and R. A. Speirer. Development of a Method To Detect Geologic Faults and Other Linear Features From LANDSAT Images. BuMines RI 8413, 1980, 74 pp.

Chekan, G. J., and D. R. Babich. Investigation of Longwall Gateroad Roof Support Characteristics at Powhatan No. 4 Mine. Instrumentation Plan. BuMines RI 8628, 1982, 9 pp.

Cummings, R. A., M. M. Singh, S. E. Sharp, and A. W. Laurito. Control of Shale Roof Deterioration With Air Tempering: Volume 1—Field and Laboratory Investigations. BuMines OFR 41(1)-82, Jan. 9, 1981, 164 pp.; NTIS, PB 82-199985.

———. Control of Shale Roof Deterioration With Air Tempering. Volume II—Annotated Bibliography. BuMines OFR 41(2)-82, Jan. 9, 1981, 64 pp.; NTIS, PB 82-199993.

de Bakker, P., A. Harvey, M. Cleary, and T. Hawkes. Development of Roof Control Techniques for Massive Roof Problems in Longwall Operations. BuMines OFR 115-80, November 1979, 191 pp.; NTIS, PB 81-125270.

Duvall, W. I., and J. R. Aggson. Least Squares Calculation of Horizontal Stresses From More Than Three Diametral Deformations in Vertical Boreholes. BuMines RI 8414, 1980, 12 pp.

Eash, R. D., and H. W. Kirchner. Development and Evaluation of Polymer Modified Portland Cement Concrete Lagging for Mine Openings. BuMines OFR 93-81, Oct. 1, 1980, 127 pp.; NTIS, PB 81-223331.

Ellenberger, J. L. Hazard Prediction Model Development: The Multiple Overlay Technique. Pres. at 110th Ann. AIME Meeting, Chicago, Ill., Feb. 23-27, 1981, Preprint 81-16, 6 pp.

Ewing, R. D., and E. M. Raney. The Three-Dimensional Structural Analysis of Double-Entry and Single-Entry Coal Mines. Final Report. Volume II. User's Guide for a Computer Program for Analytical Modeling of Rock-Structure Interaction. BuMines OFR 16(2)-80, 1976, 291 pp.; NTIS, PB 80-150352.

Fazio, C. P., W. J. Hargreaves, Jr., D. Kribs, and R. Wachtler. Evaluation of Mine Roof Bolter Components. Volume I. BuMines OFR 135(1)-80, November 1978, 228 pp.

Ferm, J. C., R. A. Melton, G. D. Cummins, D. Mathew, L. McKenna, C. Muir, and G. Norris. A Study of Roof Falls in Underground Mines on the Pocahontas #3 Seam, Southern West Virginia and Southwestern Virginia. BuMines OFR 36-80, September 1978, 92 pp.; NTIS, PB 80-158983.

Finlay, W. L. The Field Testing of Several Mine Roof Fall Alarm Systems in an Anticipated Natural Roof Fall in the White Pine Mined-Out Windpipe Area. BuMines OFR 50-80, June 30, 1978, 96 pp.; NTIS, PB 80-174261.

Fisher, C., Jr. Microseismic Roof Fall Warning System Development. Field Trials and Commercial Prototype Fabrication. Volume II. Appendix C: Coal Mine Data Collection Summary. Final Report. BuMines OFR 163(2)-81, May 30, 1980, 228 pp.; NTIS, PB 82-137845.

Fisher, C., Jr., and R. H. Thompson. Microseismic Roof Fall Warning System Development. Field Trials and Commercial Prototype Fabrication. Volume I. Final Report. BuMines OFR 163(1)-81, May 30, 1980, 197 pp.; NTIS, PB 82-137837.

Forst, G. L. Identify and Evaluate Lightweight Support Substitutes. BuMines OFR 67-80, Sept. 30, 1978, 63 pp.; NTIS, PB 80-190580.

Fowler, J. C., S. D. Hale, and R. T. Houck. Coal Mine Hazard Detection Using Synthetic Pulse Radar. BuMines OFR 79-81, January 1981, 86 pp.; NTIS, PB 81-224412.

Gerdeen, J. C., V. W. Snyder, G. L. Viegelahn, and J. Parker. Design Criteria for Roof Bolting Plans Using Fully Resin-Grouted Nontensioned Bolts To Reinforce Bedded Mine Roof. Volume I. Executive Summary and Literature Review. BuMines OFR 46(1)-80, July 22, 1977, 208 pp.; NTIS, PB 80-180052.

———. Design Criteria for Roof Bolting Plans Using Fully Resin-Grouted Nontensioned Bolts To Reinforce Bedded Mine Roof. Volume II. Field Survey. BuMines OFR 46(2)-80, July 22, 1977, 167 pp.; NTIS, PB 80-180060.

———. Design Criteria for Roof Bolting Plans Using Fully Resin-Grouted Nontensioned Bolts To Reinforce Bedded Mine Roof. Volume III. Experimental Model Studies. BuMines OFR 46(3)-80, July 22, 1977, 128 pp.; NTIS, PB 80-180078.

———. Design Criteria for Roof Bolting Plans Using Fully Resin-Grouted Nontensioned Bolts To Reinforce Bedded Mine Roof. Volume IV. Theoretical Analysis. BuMines OFR 46(4)-80, July 22, 1977, 81 pp.; NTIS, PB 80-180086.

———. Design Criteria for Roof Bolting Plans Using Fully Resin-Grouted Nontensioned Bolts To Reinforce Bedded Mine Roof. Volume V. Synthesis and Design Criteria. BuMines OFR 46(5)-80, July 22, 1977, 129 pp.; NTIS, PB 80-180094.

———. Design Criteria for Roof Bolting Plans Using Fully Resin-Grouted Nontensioned Bolts To Reinforce Bedded Mine Roof. Volumes I Through V. BuMines OFR 46(1)—(5)-80 (set), July 22, 1977, 713 pp.; NTIS, PB 80-180045 (set).

Gerdeen, J. C., G. L. Viegelahn, V. W. Snyder, P. M. Schwab, H. Schuyten, C. J. Wick, and T. J. Collison. Finite Element Analysis Applied to Resin and Mechanical Roof Bolting Systems for Strata Bound Deposits. Volume I. Final Report. BuMines OFR 123(1)-81, Aug. 31, 1976, 143 pp.

———. Finite Element Analysis Applied to Resin and Mechanical Roof Bolting Systems for Strata Bound Deposits. Volume II. Final Report. BuMines OFR 123(2)-81, Aug. 31, 1976, 48 pp.

———. Finite Element Analysis Applied to Resin and Mechanical Roof Bolting Systems for Strata Bound Deposits. Volume III. Final Report. BuMines OFR 123(3)-81, Aug. 31, 1976, 88 pp.

———. Finite Element Analysis Applied to Resin and Mechanical Roof Bolting Systems for Strata Bound Deposits. Volume IV. Final Report. BuMines OFR 123(4)-81, Aug. 31, 1976, 103 pp.

Gibbons, M., A. J. Farstad, and R. F. Kehrman. Resistivity Roof Fall Warning System in the White Pine Mine. BuMines OFR 53-80, Mar. 15, 1979, 75 pp.; NTIS, PB 80-186547.

Gordon, R. W., and G. O. Baker. High Speed Drill Probe To Detect Abandoned Underground Workings. BuMines OFR 5-82, June 1981, 57 pp.; NTIS, PB 82-146267.

Haas, C. J., R. L. Davis, H. D. Keith, J. Dave, W. C. Patrick, and J. R. Strosnider, Jr. An Investigation of the Interaction of Rock and Types of Rock Bolts for Selected Loading Conditions. BuMines OFR 51-80, 1976, 398 pp.

Hakes, G., and T. Haviland. Remote Operator Coal Mine

Roof Bolter Concepts Utilizing Existing Techniques and Components. BuMines OFR 39-80, 1978, 169 pp.; NTIS PB 80-167455.

Hamilton, W. H., and J. Brace. Development of a Lightweight Air Powered Drill Tool for Probe Drilling in Anthracite Mines. BuMines OFR 16-81, Dec. 1979, 38 pp.; NTIS, PB 81-166282.

Hanson, D. R., and G. A. Rowell. Electromagnetic Radiation From Rock Failure. BuMines RI 8594, 1982, 21 pp.

Haramy, K. Y. Borehole Shear Tester: Equipment and Technique. BuMines IC 8867, 1981, 19 pp.

Hardy, H. R., Jr., B. A. Anani, and A. W. Khair. Microseismic Monitoring of a Longwall Coal Mine. Volume III—Field Study of Mine Subsidence. BuMines OFR 30(3)-80, Oct. 31, 1977, 140 pp.; NTIS, PB 80-163413.

Hardy, H. R., Jr., and L. A. Beck. Microseismic Monitoring of a Longwall Coal Mine. Volume II—Determination of Seismic Velocity. BuMines OFR 30(2)-80, Oct. 31, 1977, 232 pp.; NTIS PB 80-163405.

Hardy, M. P., [illegible] C. Christianson. Hybrid Computer System for Optim[illegible] of Extraction Procedures in Tabular Coal Deposits. Bu[illegible]s OFR 66-82, February 1977, 70 pp.; NTIS, PB 82-204868.

Hardy, H. R., Jr., G. L. Mowrey, and E. J. Kimble, Jr. Microseismic Monitoring of a Longwall Coal Mine. Volume I—Microseismic Field Studies. BuMines OFR 30(1)-80, Aug. 31, 1978, 319 pp.; NTIS, PB 80-163397.

Hawkes, I. Measurement of Mine Roof Movement. BuMines OFR 106-80, July 1978, 238 pp.

Hellar, C., W. Elliott, and D. Hamilton. Development of a Dual-Boom Semi-Automated Roof Bolter. BuMines OFR 28-80, Aug. 31, 1979, 49 pp.; NTIS, PB 80-158793.

Hermanson, W., and R. Wachtler. Final Design Report on a Remote Controlled Hi-Roof Bolting Machine for Use in High Roof Areas of Coal Mines. BuMines OFR 113-82, July 1979, 114 pp.

Houseknecht, D. W. Probability of Encountering Coalbed Discontinuities During Vertical and Horizontal Borehole Drilling. BuMines RI 8665, 1982, 21 pp.

Houseknecht, D. W., and A. T. Iannacchione. Anticipating Coal Mining Problems in Hartshorne Formation, East-Central Oklahoma, Using Sedimentary Facies Analysis. Am. Assoc. Pet. Geol. Bull., v. 64, No. 5, May 1980, p. 724; Okla. Geol. Notes, v. 40, No. 5, October 1980, p. 209.

Hundman, G. J. Evaluation of Mine Roof Bolter Components. Volume II. BuMines OFR 135(2)-80, November 1978, 122 pp.

Hylbert, D. K. Delineation of Geologic Roof Hazards in Selected Coal Beds in Eastern Kentucky With Landsat Imagery Studies in Eastern Kentucky and the Dunkard Basin. BuMines OFR 166-81, Nov. 14, 1980, 100 pp.; NTIS, PB 82-140336.

Iannacchione, A. T., J. P. Ulery, F. E. Chase, D. M. Hyman, and D. G. Puglio. Predicting Zones of Potentially Unstable Coal Mine Roof Based on Consideration of Sedimentary Facies: A Case Study. Pres. at 1980 Ann. Meeting, Geol. Soc. of America, Atlanta, Ga., Nov. 17-20, 1980, abs. with Programs, v. 12, No. 7, p. 453.

Iannacchione, A. T., J. P. Ulery, D. M. Hyman, and F. E. Chase. Geologic Factors in Predicting Coal Mine Roof-Rock Stability in the Upper Kittanning Coalbed, Somerset County, Pa. BuMines RI 8575, 1981, 41 pp.

Jansky, J. H., and P. W. Jeran. Determination of Geologic Features Associated With Linears. BuMines RI 8660, 1982, 8 pp.

Kendorski, F. S., I. Khosla, and M. M. Singh. Criteria for Determining When a Body of Surface Water Constitutes a Hazard to Mining. BuMines OFR 45-81, Aug. 31, 1979, 363 pp.; NTIS, PB 81-194938.

Kendorski, F. S., S. D. Singh, and M. M. Singh. Development and Testing of Self-Drilling Roof Bolts. BuMines OFR 102-82, August 1979, 225 pp.

Kirkpatrick, C. G. Tiltmeter Data Analysis Windpipe Project, White Pine. BuMines OFR 66-80, July 13, 1979, 45 pp.; NTIS, PB 80-190572.

Ko, K. C. Flexible Liner for Use in Advanced Tailgate. BuMines OFR 6-82, November 1980, 191 pp.; NTIS, PB 82-149352.

Krausse, H.-F., H. H. Damberger, W. J. Nelson, S. R. Hunt, C. T. Ledvina, C. G. Treworgy, and W. A. White. Engineering Study of Structural Geologic Features of the Herrin (No. 6) Coal and Associated Rock in Illinois. Volume 1—Summary Report. BuMines OFR 96(1)-80, June 1979, 67 pp.; NTIS, PB 80-219454.

———. Engineering Study of Stuctural Geologic Features of the Herrin (No. 6) Coal and Associated Rock in Illinois. Volume 2—Detailed Report. BuMines OFR 96(2)-80, June 1979, 218 pp.; NTIS, PB 80-219462.

Kripakov, N. P. Analysis of Pillar Stability on Steeply Pitching Seam Using the Finite Element Method. BuMines RI 8579, 1981, 33 pp.

Kwitowski, A. J., and L. V. Wade. Reinforcement Mechanisms of Untensioned Full-Column Resin Bolts. BuMines RI 8439, 1980, 37 pp.

Lang, T. A., and J. A. Bishoff Research Study of Coal Mine Rock Reinforcement. BuMines OFR 72-82, January 1981, 227 pp.; NTIS, PB 82-218041.

Lang, T. A., J. A. Bischoff, and P. L. Wagner. A Program Plan for Determining Optimum Roof Bolt Tension. Theory and Application of Rock Reinforcement in Coal Mines. Volume 1 of 2. BuMines OFR 60(1)-80, 1979, 257 pp.; NTIS, PB 80-179195.

———. A Program Plan for Determining Optimum Roof Bolt Tension. Theory and Application of Rock Reinforcement in Coal Mines. Volume 2 of 2 (General Bibliography). BuMines OFR 60(2)-80, 1979, 43 pp.; available from NTIS, PB 80-179187.

Langland, R. T. Analytical Modeling of Coal Mine Roof Behavior. BuMines OFR 41-81, October 1978, 99 pp.; NTIS, UCRL-52586.

Lepper, C. M. Guidelines for Selecting Seismic Detectors for High-Resolution Applications. BuMines RI 8599, 1981, 37 pp.

Lepper, C. M., A. P. Poland, and C. T. Mullis. A Microseismic System for Monitoring Slope Stability. BuMines RI 8641, 1982, 64 pp.

Lu, P. H. Determination of Ground Pressure Existing in a Viscoelastic Rock Mass by Use of Hydraulic Borehole Pressure Cells. Pres. at Internat. Symp. on Weak Rock, Tokyo, Japan, Sept. 21-24, 1981, 7 pp.

Lusignea, R., K. Maser, and M. McCoy. Development of a Device for Evaluation of Resin Bolt Installations. BuMines OFR 128-80, December 1979, 125 pp.; available from NTIS, PB 81-130841.

Mangelsdorf, C. P. Evaluation of Roof Trusses, Phase I. BuMines OFR 56-82, February 1979, 111 pp.; NTIS, PB 82-209768.

Maus, C. W. Full Scale Model Roof Bolt Test System. Final Report. BuMines OFR 34-82, Jan. 31, 1980, 157 pp.; NTIS, PB 82-185471.

McHuron, D. C. Application of Weathering Protection at the Face. BuMines OFR 71-81, Aug. 19, 1980, 50 pp.; NTIS, PB 81-223380.

McVey, J. R., and W. L. Howle. New Closure Rate Instruments for Retreat Mining Operations. Min. Eng., v. 33, No. 12, December 1981, pp. 1699-1700.

Moebs, N. N. The Geologic Character of Some Coal Wants at the Westland Mine in Southwestern Pennsylvania. BuMines RI 8555, 1981, 25 pp.

Moebs, N. N., and J. L. Ellenberger. Geologic Structures in Coal Mine Roof. BuMines RI 8620, 1982, 16 pp.

Moebs, N. N., and J. C. Ferm. The Relation of Geology to Mine Roof Conditions in the Pocahontas No. 3 Coalbed. BuMines IC 8864, 1982, 8 pp.

Moore, T. C., L. H. Rorden, and C. Kwong. Borehole Location System Concept Demonstration Tests. BuMines OFR 28-82, May 5, 1978, 69 pp.

Morris, R. L., and J. C. Purcupile. Developing a New Method for Roof Support Using Sonic Pin-Setting Machines. BuMines OFR 7-82, Dec. 21, 1977, 95 pp.

Nichols, R. O., and P. J. Hoet. Temporary Face Support System. BuMines OFR 18-82, May 1980, 155 pp.

Panek, L. A. Comparative Cavability Studies at Three Mines. Ch. 9 in Design and Operation of Caving and Sublevel Stoping Mines, pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 91-106.

_____. Deformation and Cracking of a Concrete-Lined Tunnel in a Rock Mass Subjected to a Changing State of Strain. Proc. 22d Symp. on Rock Mechanics, Cambridge, Mass., June 29-July 2, 1981, pp. 328-334.

_____. Estimating Mine Pillar Strength From Compression Tests. Trans. Soc. Min. Eng. AIME, v. 268, 1981, pp. 1749-1761.

_____. Geotechnical Factors in Undercut-Cave Mining. Underground Mining Methods Handbook, pub. by Society of Mining Engineers of AIME, New York, 1982, pp. 1456-1465.

_____. Ground Movements Near a Caving Stope. Ch. 24 in Design and Operation of Caving and Sublevel Stoping Mines, pub. by Society of Mining Engineers of AIME, New York, 1981, pp. 329-354.

Panek, L. A., and W. J. Tesch. Monitoring Ground Movements Near Caving Stopes—Methods and Measurements. BuMines RI 8585, 1981, 108 pp.

Pariseau, W. G. Interpretation of Rock Mechanics Data (Vol. I)(A Two-Dimensional Finite Element Approach to the Evaluation of Underground Coal Mine Stability). BuMines OFR 47(1)-80, 1978, 172 pp.

_____. Interpretation of Rock Mechanics Data (Vol. II)(A Guide to Using UTAH2). BuMines OFR 47(2)-80, 1978, 41 pp.

Pennsylvania State University, Staff. Microseismic Monitoring of a Longwall Coal Mine. BuMines OFR 30(1)—(3)-80 (set), Aug. 31, 1978, 691 pp.; NTIS, PB 80-163389 (set).

Phillips, E. L. Laboratory Analysis of Pozzolan (Fly Ash) Concrete. BuMines RI 8584, 1981, 27 pp.

Radcliffe, D. E., and R. M. Stateham. Long-Term Response of a Coal Mine Roof to Time Lapse Between Exposure and Support. BuMines TPR 110, 1980, 12 pp.

_____. Stress Distribution Around Resin-Grouted Bolts. BuMines RI 8440, 1980, 39 pp.

Rockaway, J. D., and R. W. Stephenson. Investigation of the Effects of Weak Floor Conditions on the Stability of Coal Pillars. BuMines OFR 12-81, July 1979, 227 pp.; NTIS, PB 81-181109.

Simpson, R. E., J. E. Fraley, and D. J. Cox. Inorganic Cement for Mine Roof-Bolt Grouting. BuMines RI 8494, 1980, 32 pp.

Singh, M. M. Effectiveness of Inclined Roof Bolts in Coal Mines. BuMines OFR 40-80, July 1978, 115 pp.; NTIS, PB 80-167430.

Sites, K. R., and L. A. Millonzi. Tape Recording and Triggering Systems. BuMines OFR 116-81, June 7, 1980, 16 pp.; NTIS, PB 81-243248.

Stingelin, R. W., J. R. Kern, and S. L. Morgan. Pre-Mining Identification of Hazards Associated With Coal Mine Roof Measures. BuMines OFR 167-81, Mar. 30, 1979, 208 pp.; NTIS, PB 82-140344.

Suhler, S. A., T. E. Owen, J. E. Hipp, and W. R. Peters. Development of a Deep Penetrating Borehole Geophysical Technique for Predicting Hazards Ahead of Coal Mining. BuMines OFR 77-80, July 5, 1978, 124 pp.; NTIS, PB 80-208614.

Swanson, R. K., and G. L. Burkhardt. Investigation of Shank Tension in Mine Roof Bolts. BuMines OFR 82-80, May 1979, 29 pp.; NTIS, PB 80-210016.

Tandanand, S. Development of a Mechanical Roof Breaker for Ground Control in Longwall Operations Under Massive Roof. BuMines RI 8416, 1980, 20 pp.

Tate, E. E., and B. O. Blout. Development of a Mobile, Hi-Rise Work Platform. BuMines OFR 43-82, April 1981, 56 pp.

Thill, R. E., and J. A. Jessop. Engineering Properties of Coal Measure Rocks. Pres. at 111th SME-AIME Ann. Meeting, Dallas, Tex., Feb. 14-18, 1982, SME Preprint 82-146, 26 pp.

Van Dillen, D. E. The Three-Dimensional Structural Analysis of Double-Entry and Single-Entry Coal Mines. Final Report. Volume III. Three-Dimensional Finite Element Analyses of Single- and Double-Entry Portions of Sunnyside Mine No. 1. BuMines OFR 16(3)-80, 1978, 278 pp.; NTIS, PB 80-150350.

Van Dillen, D. E., and R. W. Fellner. Comparisons of Structural Stability for Entry Configurations and Ground Support for Longwall Panel Development. BuMines OFR 50-82, February 1981, 225 pp.; NTIS, PB 82-201864.

Van Dillen, D. E., K. C. Ko, F. M. Jenkins, and W. J. Karwoski. Stability Comparisons of Longwall Panel Entries Using Finite-Element Analysis. Proc. 21st U.S. Symp. on Rock Mechanics, Rolla, Mo., May 27-30, 1980, pp. 1-8.

Wade, L. V., and P. J. Conroy. Rock Mechanics Study of a Longwall Panel. Min. Eng., v. 32, No. 12, December 1980, pp. 1728-1734.

Wisecarver, D. W., and J. K. Greenlee. Steep Seam Longwall. Pres. at AIME Ann. Meeting, Chicago, Ill., Feb. 23-26, 1981. Pub. in Longwall and Shortwall Mining—State of the Art, AIME, pp. 211-215.

Industrial Hazards

Aldridge, M. D. (ed.). Proceedings of the Fourth WVU Conference on Coal Mine Electrotechnology, August 2-4, 1978. BuMines OFR 107-81, Oct. 1, 1978, 521 pp.

Bartel, E. W., M. Fox, E. Borgoyn, and P. Wingfield. TDRM (Time Domain Reflectometry Microcomputer) Testing. BuMines OFR 60-82, November 1980, 212 pp.

Bartholomae, R. C., B. S. Murray, and R. Madden. Vibration Qualification of Electronic Instrumentation for Underground Coal Mining Machinery. BuMines IC 8883, 1982, 9 pp.

Beith, B., and M. Sanders. Study of the Use of Personal Equipment in Low Coal. Experiments on Personal Equipment for Low Seam Coal Miners. V. Effect of Reflectorized Outer Garments on Detection and Conspicuity of Miners. Phase II Report, No. 5. BuMines OFR 39(6)-82, Jan. 31, 1980, 43 pp.; NTIS, PB 82-218181.

Bendersky, D., J. E. Golob, V. W. Klein, and D. R. Keyes.

Fiber Optics Technology for Underground Mine Communication Systems. BuMines OFR 77-82, January 1982, 170 pp.

Bendersky, D., and V. W. Klein. Electrical Practices in Metal/Non-Metal Mines and Mills. Mine Power Systems, Mill Power Systems, Federal Regulations, Electrical Accidents. BuMines OFR 134-80, Mar. 4, 1980, 308 pp.; NTIS, PB 81-130726.

Bendersky, D., V. W. Klein, and D. R. Keyes. Electrical Practices in Metal/Non-Metal Mines and Mills. Old Electrical Power Systems, Equipment, and Practices. BuMines OFR 24-81, October 1980, 102 pp.; NTIS, PB 81-179400.

Blake, T., M. Sanders, G. Krohn, D. Wick, K. Volkmer, and B. Beith. Study of the Use of Personal Equipment in Low Coal. Experiments on Personal Equipment for Low Seam Coal Miners: IV. Incorporating Coiled Cord Into Cap Lamp Battery Cords. Phase II Report, No. 4. BuMines OFR 39(5)-82, Jan. 31, 1980, 30 pp.; NTIS. PB 82-218172.

Bongarra, J., Jr., W. Carswell, K. Golas, E. Shriver, S. Shriver, and C. Condon. A Training Program for Conventional and Raise Drill Shaft Construction Personnel. BuMines OFR 106-81, July 1979, 414 pp.; NTIS, PB 81-237372.

Bredeson, J. G., J. L. Kohler, and H. Singh. Data Security for In-Mine Transmission. Final Report—Part I. BuMines OFR 76-81, February 1981, 111 pp.; NTIS, PB 81-221988.

Burr, J. F., and H. M. Dushac. Portable Remote Control Circuit Breaker System for Mine Trolleylines. BuMines OFR 142-81, June 1, 1978, 117 pp.; NTIS, PB 82-128067.

Butman, R. C., and W. P. Harris. Lincoln Terminal System Support Facilities Development. BuMines OFR 130-80, July 17, 1979, 43 pp.; NTIS, PB 81-130742.

Cawley, J. C. Guidelines for Carrier Phone Systems: Installation, Maintenance and Improvement. BuMines Handbook 2-81, 1981, 69 pp.

Conroy, G. J., and J. H. Green. Electrical Energy Required to Cut and Deliver Coal Out of a Continuous Miner Section. Trans. Soc. Min. Eng., AIME, v. 266, 1980, pp. 1929-1935.

Cooley, W. L., and H. W. Hill, Jr. Develop Grounding Practices for Metal/Non-Metal Mines. BuMines OFR 154-81, Feb. 27, 1981, 235 pp.; NTIS, PB 82-137308.

Cooley, W. L., and R. L. King. Guide to Substation Grounding and Bonding for Mine Power Systems. BuMines IC 8835, 1980, 27 pp.

Cooley, W. L., and R. L. McConnell. Development of Tests and Criteria To Evaluate Grounding Systems. BuMines OFR 103-81, November 1980, 176 pp.; NTIS, PB 81-238354.

———. Mine Grounding Systems. Evaluation of In-Mine Grounding System Codification of Ground Bed Construction and Measurement Techniques. BuMines OFR 23-81, June 30, 1979, 300 pp.; NTIS, PB 81-178881.

———. Mine Grounding Systems: Development of Tests and Criteria To Evaluate Grounding Systems. BuMines OFR 52-82, September 1979, 150 pp.; NTIS, PB 82-209719.

Cory, T. S. Electromagnetic Propagation in Low Coal Mines at Medium Frequencies. BuMines OFR 63-82, June 12, 1978, 96 pp.; NTIS, PB 202656.

Cosby, J. R., G. B. Gilbert, and J. H. Stoudenmire. Detection Instrumentation for Cable Shield Defects. BuMines OFR 33-81, Aug. 29, 1980, 50 pp.; NTIS, PB 81-194540.

Crooks, W. H., K. L. Drake, T. J. Perry, N. D. Schwalm, B. F. Shaw, and B. R. Stone. Analysis of Work Areas and Tasks To Establish Illumination Needs in Underground Metal and Nonmetal Mines. Volume I of II. BuMines OFR 111(1)-81, Sept. 18, 1980, 254 pp.; NTIS, PB 81-236804.

———. Analysis of Work Areas and Tasks To Establish Illumination Needs in Underground Metal and Nonmetal Mines. Volume II of II: Appendices. BuMines OFR 111(2)-81, Sept. 18, 1980, 239 pp.; NTIS, PB 81-236812.

Cummins, D., and S. F. Pangerl. Preventing Large-Battery Explosions. BuMines IC 8842, 1981, 11 pp.

Dresch, H. E. Development of an Explosion Proof High Voltage Cable Connector. BuMines OFR 149-81, Feb. 5, 1981, 32 pp.; NTIS, PB 82-142589.

Engel, J. C., and G. F. Saletta. Keep Alive Mercury Mine Lighting System. BuMines OFR 70-82, June 15, 1979, 57 pp.

Farstad, A. J., L. R. Robinson, and G. H. Saum. Mine Personnel Locator and Mine Activity Controller. Final Report. BuMines OFR 80-82, Dec. 17, 1981, 187 pp.; NTIS, PB 82-235979.

Fleming, M. S., and C. Geopferich. Investigation of a Reliable Central Lubrication System for Underground Mining Equipment. BuMines OFR 23-80, 1979. 73 pp.; NTIS, PB 80-149420.

Francis, P. H., and J. Lankford. Recommended Acceptance Testing Criteria for Adhesives and Sealants for Explosion-Proof Electrical Enclosures. BuMines OFR 129-80, Jan. 9, 1980, 67 pp.; NTIS, PB 81-128738.

Frank, W., Jr. Design and Testing of Joining Sleeves for Trailing Cable Ground and Pilot Wires. BuMines OFR 55-82, August 1979, 121 pp.; NTIS, PB 82-205725.

Gavan, G. R., C. W. Harper, L. Schaeffer, and J. L. Woodward. Coal Mine Equipment Population and Characterization and Protective Structure Status, Volume I. BuMines OFR 40(1)-81, Oct. 20, 1978, 222 pp.; NTIS, PB 81-194946.

Gavan, G. R., P. Mote, D. Strassel, and K. Conway. Development and Demonstration of Improved Truck Ladders. BuMines OFR 87-81, Sept. 28, 1979, 335 pp.; NTIS, PB 81-223406.

Gavan, G. R., D. P. Strassel, and D. A. Johnson. The Development of Improved Ingress-Egress Systems for Large Haulage Trucks. Pres. at SAE Earthmoving Industry Conf., Peoria, Ill., Apr. 14-16, 1980, SAE Tech. Paper 800680, 7 pp.

Gavan, G. R., and K. Winters. Coal Mine Equipment Population and Characterization and Protective Structure Status, Volume II. BuMines OFR 40(2)-81, Mar. 15, 1979, 125 pp.; NTIS, PB 81-194953.

Gillenwater, B., and J. McCoy. Innovative Techniques in Trolley Line Power Distribution. BuMines OFR 49-82, May 1981, 79 pp.; NTIS, PB 82-201815.

Goldberg, K. E., and R. Silliman. Development and Validation of a Miner's Instructional Procedures for Improved Safety Training. BuMines OFR 25-81, July 1980, 37 pp.; NTIS, PB 81-179426.

Goldstein, R. An Interactive Computer System for Evaluating Coal Mine Illumination. BuMines OFR 110-80, March 1980, 21 pp.; NTIS, PB 81-125528.

———. Modifications Made to an Interactive Computer System for Evaluating Coal Mine Illumination. BuMines OFR 101-81, August 1980, 27 pp.; NTIS, PB 81-236754.

Gordon, R. W., and G. O. Baker. High Speed Drill Probe To Detect Abandoned Underground Workings. BuMines OFR 5-82, June 1981, 57 pp.; NTIS, PB 82-146267.

Green, C. E. Develop Safety Practices for Electrokinetic Treatment of Mine Waste. BuMines OFR 34-80, July 1979, 75 pp.; NTIS, AD-A07295.

Green, T. C., J. P. Cater, and J. H. Nixon. Evaluation of Proximity Warning Devices, Phase II. BuMines OFR 112-81, Feb. 13, 1981, 40 pp.; NTIS, PB 81-237513.

Gunderman, R. J. Concept Study Shuttle Car Cable Reel. BuMines OFR 98-80, April 1980, 77 pp.; NTIS, PB 80-219371.

———. Innovations for Explosionproof Electrical Enclo-

sures. BuMines OFR 121-81, April 1980, 209 pp.; NTIS, PB 82-104936.

Hahn, W. F., and G. L. Brown. Modify and Evaluate a Self-Propelled Battery Powered Scoop. BuMines OFR 53-82, Sept. 5, 1980, 73 pp.; NTIS, PB 82-209727.

Hahn, W. F., and C. G. Howard. Design and Develop Feasible Lighting System for Conventional Slope Under Construction. BuMines OFR 61-81, September 1981, 83 pp.

Hahn, W. F., and S. J. Ryba. Development and Evaluation of an Illumination System for Continuous Miners That are Utilized in the Extraction of Trona. BuMines OFR 31-81, Mar. 24, 1980, 73 pp.; NTIS, PB 81-194474.

Harley, J. L., Jr. Improved Hardware for Trolley Wire Phone Systems. BuMines OFR 49-81, March 1979, 55 pp.; NTIS, PB 81-214363.

Harrow, R. A. An Illumination System for a Shortwall Mining Section. BuMines OFR 114-80, Sept. 28, 1979, 177 pp.; NTIS, PB 81-128019.

Hassan, M. M., and E. K. Stanek. Mine Electrical Power Systems. Transients Protection, Reliability Investigation, and Safety Testing of Mine Electrical Power Systems. Vol. III—Optimal Design of Mine Electrical Power Systems. BuMines OFR 6(3)-81, August 1979, 53 pp.; NTIS, PB 81-166787.

Hipp, J. E., F. D. Henson, P. E. Martin, and G. N. Phillips. Evaluation of Proximity Warning Devices. BuMines OFR 22-80, Feb. 22, 1980, 136 pp.; NTIS, PB 80-144413.

Hoadley, D. J., and B. C. Brunelle. Development of a Man and Supply Hoisting System for Underground Metal and Nonmetal Mines. Volume I. Final Report. BuMines OFR 129(1)-81, April 1981, 148 pp.; NTIS, PB 82-113366.

———. Development of a Man and Supply Hoisting System for Underground Metal and Nonmetal Mines. Operation and Maintenance Manual. Volume II. Final Report. BuMines OFR 129(2)-81, April 1981, 101 pp.

Howard, C. G., B. H. W. Pinkston, and F. Hayashi. Feasibility Analysis of Implementing Rail Car Brakes in Underground Mines. BuMines OFR 56-81, Oct. 1, 1979, 119 pp.; NTIS, PB 81-215360.

Isberg, R. A., H. Kramer, and D. A. Parrish. The Implementation of UHF Radio Communications and CCTV Monitoring Systems in a Room and Pillar Metal/Non-Metal Mine. BuMines OFR 131-81, March 1981, 132 pp.; NTIS, PB 82-116674.

Jentgen, R. L. Hoist Rope Lubrication Criteria. BuMines OFR 65-80, July 1978, 209 pp.; NTIS, PB 80-182959.

Johnson, G. A. Improved Visibility Systems for Large Haulage Trucks. Pres. at SAE Internat. Off-Highway Vehicle Meeting and Exposition, Milwaukee, Wis., Sept. 8-11, 1980, SAE Tech. Paper 800934, 9 pp.

———. Surface Haulage Accidents—Causes and Cures. Proc. 12th Ann. Inst. Coal Mining Health and Safety Res., Virginia Polytechnic Institute, Blacksburg, Va., Aug. 25-27, 1981, pp. 107-110.

Johnson, D. A., G. R. Gary, and D. P. Strassel. Improved Ingress/Egress Systems for Large Haulage Trucks. Pres. at SME-AIME Fall Meeting and Exhibition, Minneapolis, Minn., Oct. 22-24, 1980, SME Preprint 80-406, 15 pp.

Jones, R. M., W. G. Freeman, M. L. Cristo, and L. Atterbery. Improved Tire Inspection for Large Mobile Mining Equipment. BuMines OFR 44-81, September 1979, 140 pp.; NTIS, PB 81-194532.

Ketler, A. E. Evaluation of Fluorescent Lighting Systems for Various Underground Coal Mines. BuMines OFR 112-80, May 1979, 110 pp.; NTIS, PB 81-125262.

Kacmar, R. M. Reliability of Computerized Mine-Monitoring Systems. BuMines IC 8882, 1982, 10 pp.

King, R. H., B. L. Fisher, and L. A. Morley. Trailing Cables and Splices: Shielded Cables. BuMines OFR 81-80, Feb. 29, 1980, 69 pp.; NTIS, PB 80-208135.

Kiefer, J. A., and J. L. Kohler. Ground Fault and Overcurrent Protection Criteria for Coal Mine AC Distribution Systems. BuMines OFR 158-81, Oct. 31, 1980, 174 pp.; NTIS, PB 82-137001.

Kopas, P. P. Design and Development of Protective Canopies for Underground Low Coal 48" and Under. BuMines OFR 17-81, Mar. 1, 1980, 89 pp.; NTIS, PB 81-167553.

Krohn, G., M. Sanders, K. Volkmer, D. Wick, H. Miller, B. Beith, and T. Blake. Study of the Use of Personal Equipment in Low Coal. Experiments on Personal Equipment for Low Seam Coal Miners: II. Dexterity, Protection and Performance With Padded Gloves. Phase II Report, No. 2, BuMines OFR 39(3)-82, Jan. 31, 1980, 31 pp.; NTIS, PB 82-218157.

Kurtz, J. M., A. A. Bartkus, and P. J. Schram. Evaluation of Intrinsically Safe Instruments and Apparatus for Use in Underground Coal Mines. BuMines OFR 88-81, May 1980, 479 pp.

Lagace, R. L., and A. G. Emslie. Propagation of UHF Radio Waves in Limestone Room and Pillar Mines. Summary Report. BuMines OFR 27-82, January 1979, 43 pp.; NTIS, PB 82-190547.

Lagace, R. L., A. G. Emslie, and M. A. Grossman. Modelling and Data Analysis of 50 to 5000 kHz Radio Wave Propagation in Coal Mines. Technical Services for Mine Communications Research. BuMines OFR 83-80, February 1980, 109 pp.; NTIS, PB 80-209455.

Little (Arthur D., Inc.). Development of a Visual Display and Control System. BuMines OFR 78-81, October 1980, 31 pp.; NTIS, PB 81-222374.

Long, R. G., J. D. Foulkes, P. M. Kay, and S. J. Lipoff. Systems Study of Metal and Non-Metal Mine Communications. BuMines OFR 32-82, August 1979, 231 pp.

Mangolds, A. Hoist Signaling Monitor and Display System. BuMines OFR 42-82, Sept. 30, 1981, 93 pp.; NTIS, PB 82-198557.

Marshall, R., C. Mertian, and R. Winkle. Cable Handling in Surface Mines. BuMines OFR 157-81, Sept. 19, 1980, 62 pp.; NTIS, PB 82-139346.

Matanzo, F. Wire Rope Terminations. V. I. Efficiency and Service Life of Wire Rope Terminations. BuMines OFR 2(1)-81, Aug. 10, 1978, 152 pp.; NTIS, PB 81-168825.

———. Wire Rope Terminations. V. II. Selection and Inspection Guide for Wire Rope Terminations. BuMines OFR 2(2)-81, Aug. 10, 1978, 30 pp.; NTIS, PB 81-168833.

Metcalf, J. T., and F. Matanzo. Wire Rope Terminations. V. III. Training and Inspection Manual for the Assembly of Wire Rope Terminations. BuMines OFR 2(3)-81, Aug. 10, 1978, 49 pp.; NTIS, PB 81-168841.

———. Wire Rope Terminations. Volumes I Through III. BuMines OFR 2(1)—(3)-81, Aug. 10, 1978, 231 pp.; NTIS, PB 81-168817.

Morley, L. A., F. C. Trutt, and J. A. Kohler. Final Report—Evaluation of Coal-Mine Electrical-System Safety. BuMines OFR 160-81, June 1, 1981; NTIS, PB 82-139338.

Muldoon, T. L., S. Ruggieri, T. Gore, and L. B. McDonald. Design and Develop Standardized Controls in Roof Bolting Machines—Preliminary Design. BuMines OFR 107-80, April 1980, 63 pp.

Nutter, R. S., W. R. Voltz, and M. D. Aldridge. Mine Wide Test of the WVU Monitoring Concept. Phase II Final Report: Modular Mine Monitoring and Control System. BuMines OFR 103-80, Feb. 29, 1980, 273 pp.; NTIS, PB 80-227648.

Paice, D. A., D. S. Kimmel, and R. P. Putkovich.

Development of Dual Input/Dual Purpose Power Converter for Trolley Wire Operation. BuMines OFR 10-81, October 1979, 62 pp.; NTIS, PB 81-179434.

Penning, F. A., M. H. Brinkmann, and D. W. Robertson. Energy Absorption Systems for Mine Cages. Final Report, Vol. II. Study Energy Absorption Characteristics of a Pit Bottom Buffer. BuMines OFR 133(2)-81, August 1980, 139 pp.

Penning, F. A., D. R. Sorensen, and D. W. Robertson. Energy Absorption Systems for Mine Cages. Final Report, Vol. 1. Free Fall Testing of Single Tooth Safety Dogs on Keruing Guides. BuMines OFR 133(1)-81, May 1980, 214 pp.

Rivell, R. A., F. C. Trutt, and L. A. Morley. Interactive Mine-Power-System Analysis. User's Manual. Volume II. BuMines OFR 162(2)-81, Jan. 28, 1980, 239 pp.; NTIS, PB 82-138306.

Rock, B. Factory Integration of an Illumination System Into a Continuous Mining Machine. BuMines OFR 90-80, Oct. 29, 1979, 75 pp.; NTIS, PB 80-219496.

St. Amant, A. Positive Indicator for Track Switch Point Position. BuMines OFR 35-80, Feb. 28, 1978, 34 pp.; NTIS, PB 80-160815.

_____. Trolley Line Power Transfer to Vehicles. BuMines OFR 9-81, July 31, 1980, 80 pp.; NTIS, PB 81-178873.

Sanders, M. S. Visual Attention Locations for Operating Continuous Miners, Shuttle Cars, and Scoops: A Summary. BuMines OFR 29(2)-82, May 1, 1981, 67 pp.; NTIS, PB 82-187949.

Sanders, M. S., B. Beith, and T. Blake. Study of the Use of Personal Equipment in Low Coal. Use of Personal Equipment in Low Coal: A Review of the Personal Equipment Literature. Phase I Report. BuMines OFR 39(1)-82, Dec. 30, 1978, 100 pp.; NTIS, PB 82-218207.

Sanders, M. S., B. Beith, T. Blake, G. Krohn, K. Volkmer, D. Wick, and H. Miller. Study of the Use of Personal Equipment in Low Coal. Phase I Report and Phase II, Reports 1 Through 6. BuMines OFR 39(1)—(7)-82 (set), Dec. 30, 1978, 292 pp.; NTIS, PB 82-218132.

Sanders, M. S., and G. R. Kelley. Visual Attention Locations for Operating Continuous Miners, Shuttle Cars, and Scoops. Volume I. BuMines OFR 29(1)-82, Jan. 31, 1981, 142 pp.; NTIS, PB 82-187964.

Sanders, M. S., G. Krohn, K. Volkmer, D. Wick, H. Miller, T. Blake, and B. Beith. Study of the Use of Personal Equipment in Low Coal. Experiments on Personal Equipment for Low Seam Coal Miners. I. Comparison of 10/60 and Standard Self-Rescue Devices. Phase II Report, No. 1. BuMines OFR 39(2)-82, Jan. 31, 1980, 26 pp.; NTIS, PB 82-218410.

Sanders, M. S., G. Krohn, D. Wick, K. Volkmer, and B. Beith. Study of the Use of Personal Equipment in Low Coal. Experiments on Personal Equipment for Low Seam Coal Miners. III. Effect of Size and Weight of Battery Pack Performance. Phase II. Report, No. 3. BuMines OFR 39(4)-82, Jan. 31, 1980, NTIS, PB 82-218165.

Sanders, M. S., D. Wick, and G. Krohn. Study of the Use of Personal Equipment in Low Coal. Experiments on Personal Equipment for Low Seam Coal Miners. VI. Comparison Bumping Hazards With High and Low Profile Helmets. Phase II Report, No. 6. BuMines OFR 39(7)-82, Jan. 31, 1980, 29 pp.; NTIS, PB 82-218199.

Scott, L. W. Some Design Factors for Windows and Lenses Used in Explosion-Proof Enclosures. BuMines IC 8880, 1982, 9 pp.

Siedenstrang, D., D. Ellingwood, and J. Short. Manpower and Training Model for the Mining Industry. BuMines OFR 92-81, April 1980, 219 pp.; NTIS, PB 81-222325.

Smith, N. S. (ed.). Proceedings of the Fifth WVU Conference on Coal Mine Electrotechnology, July 30-31, August 1, 1980. BuMines OFR 82-81, October 1980, 396 pp.

Stanek, E. K. Enhancement of Mine Power System Safety and Reliability. BuMines OFR 116-80, October 1979, 207 pp.; NTIS, PB 81-125361.

Stanek, E. K., and M. Cobert. Mine Electrical Power Systems. Transients Protection, Reliability Investigation, and Safety Testing of Mine Electrical Power Systems. Vol. IV—Use of Programmable Calculators in Mine Power Systems Design and Analysis. BuMines OFR 6(4)-81, August 1979, 113 pp.; NTIS, PB 81-166795.

Stanek, E. K., M. M. Hassan, Y. C. Chou, and H. Shamash. Mine Electrical Power Systems. Transients Protection, Reliability Investigation, and Safety Testing of Mine Electrical Power Systems. Vol. V—Periodic Inspection of Mine Electrical Power Systems. BuMines OFR 6(5)-81, August 1979, 113 pp.; NTIS, PB 81-166803.

Stanek, E. K., W. Vilcheck, and A. Kunjara. Mine Electrical Power Systems. Transients Protection, Reliability Investigation, and Safety Testing of Mine Electrical Power Systems. Vol. I—Transients in Mine Electrical Power Systems. BuMines OFR 6(1)-81, August 1979, 169 pp.; NTIS, PB 81-166761.

Stanek, E. K., W. Vilcheck, A. Kunjara, S. S. Venkata, M. Chinnarao, E. W. Collins, E. U. Ibok, M. M. Hassan, M. Cobert, Y. C. Chou, and H. Shamash. Mine Electrical Power Systems. Transients Protection, Reliability Investigation, and Safety Testing of Mine Electrical Power Systems. Volumes I Through V. BuMines OFR 6(1)—(5)-81, August 1979, 645 pp.; NTIS, PB 81-166753.

Stefano, R., C. Bise, G. Luxbacher, and K. Katen. Cables for Face Equipment. Standardization of Requirements. Final Report. BuMines OFR 135-81, June 1, 1981, 49 pp.; NTIS, PB 82-113820.

Strycula, E. C., and D. A. Paice. Evaluation of Control and Protection Circuits. BuMines OFR 126-81, April 1981, 50 pp.; NTIS, PB 82-105065.

Swan, S. A., and L. Schaffer. Dredge Safety Hazard Analysis. Proc. World Dredging Conf., Vancouver, B. C., Canada, Oct. 29-31, 1980 (ed. by. J. Powers). Symcon Publishing Co., Long Beach, Calif., 1980, pp. 125-131.

Szpak, A. D., W. F. Hahn, and C. S. Skinner. Demonstration of Coal Mine Illumination Systems. BuMines OFR 2-82, January 1981, 127 pp.; NTIS, PB 82-147471.

Tomlinson, J., T. Rusnak, R. King, and L. Morley. Splice Testing Using a Figure-S Machine and a New Shuttle Car Simulation. BuMines OFR 80-80, July 31, 1979, 44 pp.; NTIS, PB 80-210222.

Trelewicz, K. Environmental Test Criteria for the Acceptability of Mine Instrumentation. BuMines OFR 1-82, June 1981, 137 pp.; NTIS, PB 82-146325.

Trutt, F. C., L. A. Morley, and R. A. Rivell. Interactive Mine-Power-System Analysis—APL Fault Program. BuMines OFR 131-80, Mar. 1, 1979, 109 pp.; NTIS, PB 81-130858.

_____. Interactive Mine-Power-System Analysis. Volume I. BuMines OFR 162(1)-81, Jan. 31, 1981, 209 pp.; NTIS, PB 82-138298.

Updyke, D. T., W. C. Muhler, and H. C. Turnage. An Evaluation of Leaky Feeder Communication in Underground Mines. BuMines OFR 30-81, July 1980, 104 pp.; NTIS, PB 81-194466.

U.S. Bureau of Mines, Staff. Application Notes: Mine Electric Power Systems. BuMines HB 1-81, 1981, 83 pp.

_____. Surface Mine Truck Safety. Proceedings: Bureau of Mines Technology Transfer Seminars, Minneapolis, Minn.,

June 25, 1980, Birmingham, Ala., July 9, 1980, and Tucson, Ariz., July 24, 1980. BuMines IC 8828, 1980, 61 pp.

U.S. Bureau of Mines, Staff, Pittsburgh Research Center. Ergonomics-Human Factors in Mining. Proceedings: Bureau of Mines Technology Transfer Seminars, Pittsburgh, Pa., December 31, 1981, St. Louis, Mo., December 10, 1981, and Denver, Colo., December 15, 1981. BuMines IC 8866, 1981, 167 pp.

_____. Mine Safety Education and Training Seminar. Proceedings: Bureau of Mines Technology Transfer Seminars, Pittsburgh, Pa., Dec. 9, 1980, Springfield, Ill., Dec. 12, 1980, and Reno, Nev., Dec. 16, 1980. BuMines IC 8858, 1981, 76 pp.

Uslan, S. S., H. M. Adelman, and R. S. Keller. Testing the Effects of Applied Behavioral Analysis and Applied Behavioral Management Techniques on the Safe Behaviors of Salt Mine Personnel. BuMines OFR 44-80, Sept. 30, 1978, 44 pp.; NTIS, PB 80-171309.

Venkata, S. S., M. Chinnarao, E. W. Collins, and E. U. Ibok. Mine Electrical Power Systems. Transients Protection, Reliability Investigation, and Safety Testing of Mine Electrical Power Systems. Vol. II—Reliability of Mine Electrical Power Systems. BuMines OFR 6(2)-81, August 1979, 193 pp.; NTIS, PB 81-166779.

Wait, J. R., and D. A. Hill. Electromagnetic Fields in Mine Environments. BuMines OFR 32-81, May 1, 1980, 448 pp.

Walton, D. R., P. F. Webb, and W. T. Liggett. Study To Determine the Feasibility of Man-Trip Training. Phase I Report. BuMines OFR 104-81, Jan. 23, 1979, 182 pp.; NTIS, PB 81-237471.

Westin, R. A., R. P. Burruss, and B. Woodcock. Polychlorinated Biphenyls: Regulations and Substitutes. A Compliance Manual for the U.S. Mining Industry. BuMines OFR 27-80, 1979, 89 pp.; NTIS, PB 80-157340.

Westin, R. A., R. P. Burruss, B. Woodcock, and R. L. King. Polychlorinated Biphenyls: Regulations and Substitutes. A Compliance Manual for the U.S. Mining Industry. BuMines IC 8838, 1981, 66 pp.

Whitehead, K. L., and J. C. Yingling. Development of Guidelines for Installation and Maintenance of Mine Illumination Systems. BuMines OFR 38-82, April 1981, 290 pp.; NTIS, PB 82-192022.

Woodward, J. L., L. L. Owens, R. J. McCracken, and P. I. Mate. Steering System Survey for Surface Mining Equipment. BuMines OFR 132-80, Apr. 20, 1979, 186 pp.; NTIS, PB 81-130866.

Woodward, J. L., and S. A. Swan. ROPS Field Performance—A Status Report. Pres. at SAE Earthmoving Industry Conf., Central Illinois Section, Peoria, Ill., Apr. 14-16, 1980, SAE Tech. Paper 800679, 9 pp.

Minerals and Materials Research

Extractive Metallurgy

Altringer, P.B., and P.T. Brooks. W Recovery From Searles Lake by Ion Exchange. Tungsten News, v. 18, No. 3, Summer 1980, pp. 3-4.

Altringer, P. B., P. T. Brooks, and W. A. McKinney. Selective Extraction of Tungsten From Searles Lake Brines. Sep. Sci. Technol., v. 16, No. 9, 1981, pp. 1053-1069.

Babcock, W. C., R. W. Baker, D. J. Kelly, E. D. LaChapelle, and H. K. Lonsdale. Coupled Transport Membranes for Metal Separations. BuMines OFR 67-81, August 1979, 97 pp., NTIS, PB 81-214843.

Barclay, J. A. Preparation of Cell Feed Materials for Aluminum and Magnesium Production. Pres. at Workshop on Electrochemistry Applied to Processing of Lunar Materials, Houston, Tex., Sept. 12, 1979; Space Solar Power Rev., v. 12, 1981, pp. 259-269.

Baglin, E. G., G. B. Atkinson, and L. J. Nicks. Methanol Synthesis Catalysts From Thorium-Copper Intermetallics. Preparation and Evaluation. I&EC Prod. Res. and Develop., v. 20, No. 1, March 1981, pp. 87-90.

Bengston, K. B., P. Chuberka, R. F. Nunn, A. V. San Jose, G. M. Manarolis, and L. E. Malm. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task 3 Report: Preliminary Design of 25 Ton Per Day Pilot Plant. Volume I. Process Technology and Costs. BuMines OFR 122(1)-80, November 1979, 232 pp., NTIS, PB 81-125031.

_____. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task 3 Report: Preliminary Design of 25 Ton Per Day Pilot Plant. Volume II. Appendix A. Equipment List, Specifications and Quotations. Areas 1 Through 7. BuMines OFR 122(2)-80, November 1979, 281 pp.

_____. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task 3 Report: Preliminary Design of 25 Ton Per Day Pilot Plant. Volume III. Appendix A. Equipment List, Specifications and Quotations. Area 8 Through 25. BuMines OFR 122(3)-80, November 1979, 261 pp.

_____. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task 3 Report: Preliminary Design of 25 Ton Per Day Pilot Plant. Volume IV. Appendix B. General Specifications. BuMines OFR 122(4)-80, November 1979, 201 pp.

_____. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task 3 Report: Preliminary Design of 25 Ton Per Day Pilot Plant. Volume V. Appendix B. General Specifications. BuMines OFR 122(5)-80, November 1979, 122 pp.

_____. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task 3 Report: Preliminary Design of 25 Ton Per Day Pilot Plant. Volume VI. Appendix C. Drawings. BuMines OFR 122(6)-80, November 1979, 103 pp.

Bennetts, J., E. Morrice, and M. M. Wong. Preparation of Platinum-Palladium Flotation Concentrate From Stillwater Complex Ore. BuMines RI 8500, 1981, 18 pp.

Bennington, K. O., and R. R. Brown. Thermodynamic Properties of Synthetic Acmite ($NaFe^{3}Si_2O_6$). BuMines RI 8621, 1982, 12 pp.

Bennington, K. O., J. M. Stuve, and M. J. Ferrante. Thermodynamic Properties of Petalite ($Li_2Al_2Si_8O_{20}$). BuMines RI 8451, 1980, 20 pp.

Bertke, T., D. Loudin, and D. Armentrout. Evaluation of the Environmental Factors Involved in Metallurgical Processes to Utilize Domestic Resources for Production of Alumina.

Environmental Aspects of Preliminary Pilot-Plant Design. BuMines OFR 70-81, December 1980, 48 pp.; NTIS, PB 81-225906.

Beyer, R. P. An Algorithm for Determining Debeye Temperatures. BuMines RI 8566, 1981, 5 pp.

———. A Computer Program for Calculating Thermodynamic Properties From Spectroscopic Data. BuMines IC 8871, 1982, 19 pp.

Beyer, R. P., M. J. Ferrante, and R. R. Brown. Thermodynamic Properties of $KAlO_2$. J. Chem. Thermodynamics, v. 12, 1980, pp. 985-991.

Beyer, R. P., M. J. Ferrante, R. R. Brown, and G. E. Daut. Thermodynamic Properties of Potassium, Metasilicate, and Disilicate. BuMines RI 8410, 1980, 21 pp.

Blake, R. L. Amphiboles in Soapstone Ridge, Ga. BuMines RI 8627, 1982, 17 pp.

Brown, L. L., A. R. Rule, and C. B. Daellenbach. Characterization and Beneficiation of Phosphate-Bearing Rocks From Northern Michigan. BuMines RI 8562, 1981, 16 pp.

Campbell, A. B., III. Methodology for Evaluating Integral Gaussian Profiles. BuMines IC 8811, 1980, 18 pp.

Campbell, W. J., C. W. Huggins, and A. G. Wylie. Chemical and Physical Characterization of Amosite, Chrysotile, Crocidolite, and Nonfibrous Tremolite for Oral Ingestion Studies by the National Institute of Environmental Health Sciences. BuMines RI 8452, 1980, 63 pp.

Carnahan, T. G., C. M. Flynn, Jr., and R. E. Lindstrom. Recovery of Silver From Chloride Leach Solutions by Iodide Precipitation. BuMines RI 8428, 1980, 9 pp.

———. Recovery of Silver From Chloride Leach Solutions by Iodide Precipitation. Pres. at 109th Ann. Meeting, AIME, Las Vegas, Nev., Feb. 24-28, 1980, AIME Preprint 80-77, 6 pp.

Cole, E. R., Jr., and T. J. O'Keefe. Insoluble Anodes for Electrowinning Zinc and Other Metals. BuMines RI 8531, 1981, 25 pp.

Colombo, A. F. Selective Flocculation and Flotation of Iron-Bearing Materials. Ch. in Fine Particles Processing, ed. by P. Somansundaran. American Institue of Mining, Metallurgical, and Petroleum Engineers, New York, 1980, pp. 1034-1056.

Dahlin, D. C., A. R. Rule, and L. L. Brown. Beneficiation of Potential Platinum Resources From Southeastern Alaska. BuMines RI 8553, 1981, 14 pp.

Davidson, C. F. Recovery of Lithium From Clay by Selective Chlorination. BuMines RI 8523, 1981, 19 pp.

Davis, B. E., T. O. Llewellyn, and G. V. Sullivan. Beneficiation of a Phosphate Ore Produced by Borehole Mining. BuMines RI 8681, 1982, 10 pp.

Eddy, W. H., B. E. Davis, and G. V. Sullivan. The Hawthorn Formation of Central Florida. Part II—Characterization, Evaluation, and Beneficiation of Central Florida Phosphate-Bearing Hawthorn Formation. Florida Bureau of Geol., Div. Res. Management, Rept. Inv. 91, 1982, pp. 33-57.

Eisele, J. A. Producing Alunina From Clay by the Hydrochloric Acid Process, A Bench-Scale Study. BuMines RI 8476, 1980, 21 pp.

Eisele, J. A., F. R. Smith, and D. J. Bauer. Iron Extraction From Simulated Aluminum Nitrate Leach Liquor. BuMines RI 8634, 1982, 9 pp.

Elger, G. W., W. L. Hunter, and J. E. Mauser. Preparation and Chlorination of Titanium Carbide From Domestic Titaniferous Ores. BuMines RI 8497, 1980, 20 pp.

Farley, E. P., E. L. Watson, D. D. MacDonald, R. W. Bartlett, and G. N. Krishnan. Recovery of Heavy Metals From High Salinity Geothermal Brine. BuMines OFR 91-81, December 1980, 130 pp.; NTIS PB 81-222218.

Farrell, R. F., S. A. Matthes, and A. J. Mackie. A Simple, Low-Cost Method for the Dissolution of Metal and Mineral Samples in Plastic Pressure Vessels. BuMines RI 8480, 1980, 14 pp.

Ferrante, M. J., and R. A. McCune. High-Temperature Enthalpy and X-Ray Diffraction Data for Aluminum Sulfide (Al_2S_3). BuMines RI 8526, 1981, 10 pp.

———. High-Temperature Enthalpy and X-Ray Powder Diffraction Data for ZrI_4. BuMines RI 8418, 1980, 8 pp.

Ferrante, M. J., J. M. Stuve, H. C. Ko, and R. R. Brown. Thermodynamic Properties of Aluminum Sulfide (Al_2S_3). High Temp. Sci., No. 14, 1981, pp. 91-101.

Ferrante, M. J., J. M. Stuve, and L. B. Pankratz. Thermodynamic Properties of Cuprous and Cupric Sulfides. High Temp. Sci., v. 14, 1981, pp. 77-99.

Foley, R. T., and W. T. Adams. The Electrochemical Characterization of Metallic Calcium, Strontium, and Barium Electrodes. BuMines OFR 75-81, Sept. 30, 1980, 13 pp.

Foot, D. G., Jr., and J. L. Huiatt. Direct Flotation of Potash From Insoluble-Slime-Bearing Sylvinite and Carnallite Ores. Pres. at AIME Ann. Meeting, Chicago, Ill., Feb. 22-26, 1981, SME Preprint 81-74, 8 pp.

Foot, D. G., Jr., C. E. Jordan, and J. L. Huiatt. Direct Flotation of Potash From Carnallite. BuMines RI 8678, 1982, 11 pp.

Fuerstenau, D. W. Rod Mill Grinding: Analysis of Size Reduction Kinetics and Material Transport. BuMines OFR 120-81, July 1980, 33 pp.; NTIS, PB 82-104357.

Gokcen, N. A. Multicomponent Regular Solutions. Scripta Metallurgica, v. 16, 1982, pp. 723-727.

———. Partial Pressures of Gaseous HCl and H_2O Over Aqueous Solutions of HCl, $AlCl_3$, and $FeCl_3$. BuMines RI 8456, 1980, 18 pp.

———. Retrograde Solubility in Binary Systems. Scripta Metallurgica, v. 14, 1980, pp. 1185-1187.

Gokcen, N. A. (ed. by). Chemical Metallurgy—A Tribute to Carl Wagner. AIME Symposium Series, September 1981, 506 pp.

Gokcen, N. A., R. V. Mrazek, and L. B. Pankratz (comp.). Proceedings of the Workshop on Techniques for Measurement of Thermodynamic Properties, Albany, Oreg., August 21-23, 1979. BuMines IC 8853, 1981, 438 pp.

Gomes, J. M., and G. M. Martinez. Recovery of Gold and Other Heavy Minerals From Alluvial Deposits: Equipment and Practices. Pres. at Internat. Gold/Silver Conf., Reno, Nev., May 21-23, 1981, Preprint, 12 pp.

Good, P. C. Direct Preparation of Phosphoric Acid From Intermediate-Grade Western Phosphate Shale. BuMines RI 8534, 1981, 12 pp.

Grant, D. C., K. Hennings, T. Bobick, and R. Bartholomae. A Simulation Model for Predicting the Performance of Vibrating Screens. Nat. Limestone Inst. Operations Day Program Booklet, 1982, pp. 57-72.

Hass, L. A., R. B. Schluter, and R. H. Nafziger. Low-Pressure Leaching of Duluth Complex Matte. BuMines RI 8522, 1981, 12 pp.

Hager, J. P., and H. S. Patsos. Investigation of the Formation of Vapor Complexes Between Alumina Chloride and Impurity Elements Associated With Aluminum Raw Materials. BuMines OFR 63-81, Dec. 22, 1980, 79 pp.; NTIS, PB 81-214850.

Hansen, J. P., E. G. Davis, and G. V. Sullivan. Autogenous Attrition Microgrinding of Calcium Carbonate Minerals. BuMines RI 8503, 1981, 15 pp.

Heinen, H. J., G. E. McClelland, and R. E. Lindstrom. Recovery of Gold From Arsenopyrite Concentrates by Cyanidation-Carbon Adsorption. BuMines RI 8458, 1980, 10 pp.

Hendrix, J. L. Kinetics of Chlorine Leaching of Zinc-Lead Flotation Concentrates. BuMines OFR 138-80, Feb. 4, 1980, 25 pp.; NTIS, PB 81-132482.

Henn, J. J., F. A. Peters, and R. S. Kaplan. An Assessment of a Proposed Plant for Producing Direct Reduced Iron on the Minnesota Iron Range. BuMines OFR 69-82, March 1982, 23 pp.

Hill, S. D., D. L. Pool, and G. A. Smyres. Electrowinning Zinc From Zinc Chloride in Monopolar and Bipolar Fused-Salt Cells. BuMines RI 8524, 1981, 24 pp.

Hopstock, D. M., and A. F. Colombo. Processing Finely Ground Oxidized Taconite by Wet High-Intensity Magnetic Separation. Ch. in Fine Particles Processing, ed. by P. Somansundaran. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1980, pp. 1242-1260.

Hudson, L. K., and J. K. Carnevale. Direct Calcination of $AlCl_3.6H_2O$ With Off-Gas Use for Crystallization. BuMines OFR 62-81, Jan. 12, 1979, 30 pp.; NTIS, PB 81-214827.

Huggins, C. W., and S. D. Cramer. Diffraction Jig for Philips Electronics Diffractometers. Norelco Rep., v. 27, No. 1, April 1980, p. 40.

Huggins, C. W., B. W. Haynes, and R. L. Virta. Preliminary Characterization of Pacific Manganese Nodules. Proc. Ann. Meeting, Electron Microscopy Soc. Am., Atlanta, Ga., Aug. 10-14, 1981, pp. 150-151.

Jacobs, H. D. Beneficiation of Western Mesabi Range Oxidized Taconites. A Comparison of the Anionic and Cationic Flotation Systems and an Evaluation of Potential Iron Ore Reserves. BuMines RI 8552, 1981, 21 pp.

Jacobs, H. D., and A. F. Colombo. Cationic Flotation of a Hematitic Oxidized Taconite. BuMines RI 8505, 1981, 11 pp.

_____. Selective Flocculation and Flotation of a Mesabi Range Hematitic-Goethitic Taconite. BuMines RI 8482, 1980, 11 pp.

Jones, M. M., J. S. MacDuff, and A. B. Whitehead. Spectrophotometric Determination of Uranium Using Dibenzoylmethane. BuMines RI 8433, 1980, 12 pp.

Jordan, C. E., G. V. Sullivan, and B. E. Davis. Pneumatic Beneficiation of Mica Ores. Pres. at Soc. Min. Eng., AIME, Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980, SME Preprint 80-7, 8 pp.

_____. Pneumatic Concentration of Mica. BuMines RI 8457, 1980, 24 pp.

Jordan, C. E., G. V. Sullivan, B. E. Davis, and C. P. Weaver. A Continuous Dielectric Separator for Mineral Beneficiation. BuMines RI 8437, 1980, 18 pp.

Khalafalla, S. E., and J. E. Pahlman. Selective Extraction of Metals From Pacific Sea Nodules With Dissolved Sulfur Dioxide. BuMines RI 8518, 1981, 26 pp.

_____. Selective Extraction of Metals From Pacific Sea Nodules With Dissolved Sulfur Dioxide. J. Metals, v. 33, No. 8, August 1981, pp. 37-42.

Khalafalla, S. E., and G. W. Reimers. Beneficiation With Magnetic Fluids. BuMines RI 8532, 1981, 21 pp.

_____. Preparation of Dilution-Stable Aqueous Magnetic Fluids. Pres. at 2d Internat. Conf. on Magnetic Fluids, Orlando, Fla., Mar. 24-27, 1980; IEEE Trans., v. MAG-16, No. 2, March 1980, pp. 178-183.

Kirby, R. C., and J. A. Barclay. Alumina From Nonbauxitic Resources. Proc. Internat. Committee for the Study of Bauxite, Alumina, and Aluminum, ISCOBA-AIM Conf., Cagliari, Italy, Sept. 26-28, 1979, No. 16, 1981, v. 11 pp. 1-12.

Kirby, D. E., D. R. George, and C. B. Daellenbach. Chromium Recovery From Nickel-Cobalt Laterite and Laterite Leach Residue. BuMines RI 8676, 1982, 22 pp.

Ko, H. C., N. Ahmad, and Y. A. Chang. Thermodynamics of Calcination of Calcite. BuMines RI 8647, 1982, 9 pp.

Ko, H. C., and R. R. Brown. Enthalpies of Formation of $ZnO{\cdot}2ZnSO_4$ and $CoSO_4{\cdot}6H_2O$. BuMines RI 8688, 1982, 6 pp.

Ko, H. C., and G. E. Daut. Enthalpies of Formation of alpha- and beta-Magnesium Sulfate and Magnesium Sulfate Monohydrate. BuMines RI 8409, 1980, 8 pp.

Llewellyn, T. O., B. E. Davis, G. V. Sullivan, and J. P. Hansen. Beneficiation of High-Magnesium Phosphate From Southern Florida. BuMines RI 8609, 1982, 16 pp.

Long, D. A. Quality Control in the Lake Superior Mines. Proc. 43d Minn. Sec. AIME Ann. Symp., Duluth, Minn., Jan. 14-16, 1981, pp. 26-1—26-28.

MacDonald, D. J. Computer Simulation of Zirconium-Hafnium Separation by Countercurrent Extraction. Sep. Sci. Technol., v. 16, No. 10, 1981, pp. 1355-1371.

Madsen, B. W. Determination of Ferric Ion Diffusion and Activity Coefficients From Chronopotentiometric Data. BuMines RI 8617, 1982, 23 pp.

Madsen, B. W., and M. E. Wadsworth. A Mixed Kinetics Dump Leaching Model for Ores Containing a Variety of Copper Sulfide Minerals. BuMines RI 8547, 1981, 44 pp.

Mah, A. D. Thermodynamic Data for Arsenic Sulfide Reactions. BuMines RI 8671, 1982, 85 pp.

May, J. T., C. F. Davidson, and V. E. Edlund. Extracting Lithium From McDermitt Clay. TMS-AIME Light Metals Book, 1982, pp. 1159-1168.

May, J. T., D. S. Witkowsky, and D. C. Seidel. Extracting Lithium From Clays by Roast-Leach Treatment. BuMines RI 8432, 1980, 16 pp.

Maysilles, J. H., D. E. Traut, and D. L. Sawyer, Jr. Aluminum Chloride Hexahydrate Crystallization by HCl Gas Sparging. BuMines RI 8590, 1982, 38 pp.

McCelland, G. E., and J. A. Eisele. Improvements in Heap Leaching To Recover Silver and Gold From Low-Grade Resources. BuMines RI 8612, 1982, 26 pp.

McCelland, G. E., and S. D. Hill. Heap Leaching Gold-Silver Ores With Poor Percolation Characteristics. Ch. 5 in Gold and Silver Leaching Recovery and Economics, SME-AIME, 1981, pp. 43-50.

_____. Silver and Gold Recovery From Low-Grade Resources. Min. Cong. J., v. 67, No. 5, May 1981, pp. 17-23, 41.

Mussler, R. E., and R. E. Siemens. Electrowinning Nickel and Cobalt From Domestic Laterite Processing. Preliminary Laboratory-Scale Results. BuMines RI 8604, 1982, 20 pp.

Nafziger, R. H., and R. R. Jordan. Ilmenite Reduction by a Carbon Injection Technique. Proc. 37th Electric Furnace Conf., AIME, Detroit, Mich., Dec. 4-7, 1979, v. 37, July 1980, pp. 178-189.

Nafziger, R. H., R. R. Jordan, and W. L. Hunter. Electric-Arc Furnace Processing of a Domestic Titaniferous Material. BuMines RI 8511, 1981, 35 pp.

Nafziger, R. H., P. E. Sanker, J. E. Tress, and R. A. McCune. Prereduction and Melting of Domestic Chromites. Proc. 38th Electric Furnace Conf., Iron and Steel Soc., AIME, Pittsburgh, Pa., Dec. 11-12, 1980, pp. 27-45.

Needham, P. B., Jr., W. D. Riley, G. R. Conner, and A. P. Murphy. Chemical Analyses of Brines From Four Imperial Valley, Calif., Geothermal Wells. Soc. Petrol. Eng. J., v. 20, No. 2, April 1980, pp. 105-112.

Nichols, L. D., A. S. Obermayer, and M. B. Allen. Bound Liquid Ion Exchange Membranes for the Extraction of Cobalt From Lateritic Leach Solutions. BuMines OFR 79-82, Feb. 25, 1982, 59 pp.; NTIS, PB 82-218652.

Nigro, J. N. Firing an Iron Ore Pelletizing Kiln With Low-Btu Gas From Lignite. BuMines RI 8670, 1982, 22 pp.

Nilsen, D. N., R. E. Siemens, and S. C. Rhoads. Solvent Extraction of Cobalt From Laterite-Ammoniacal Leach Liquors. BuMines RI 8419, 1980, 23 pp.

———. Solvent Extraction of Nickel and Copper From Laterite-Ammoniacal Leach Liquors. BuMines RI 8605, 1982, 29 pp.

Olsen, R. S., W. G. Gruzensky, S. J. Bullard, and J. L. Henry. Effects of Feed Preparation on HCl Leaching of Calcined Kaolinitic Clay To Recover Alumina. BuMines RI 8618, 1982, 24 pp.

Palmer, G. R., I. L. Nichols, and D. C. Seidel. Uranium Ion Exchange From Low-Grade Acidic Solutions in a Fluidized System. BuMines 8492, 1980, 20 pp.

Palmer, G. R., I. L. Nichols, R. G. Smith, and D. C. Seidel. Orifice Plate Design Studies for a Multiple-Compartment, Ion-Exchange Column. BuMines RI 8616, 1982, 17 pp.

Perry, J. A., R. F. Farrell, and A. J. Mackie. Modification of a Commercial Atomic Absorption Spectrophotometer for Cold-Vapor Determination of Mercury. BuMines RI 8573, 1981, 11 pp.

Peterson, R. E., and A. F. Colombo. Beneficiation of a Hematitic Taconite by Reduction Roasting, Magnetic Separation, and Flotation. BuMines RI 8572, 1981, 13 pp.

———. Reduction Roasting and Beneficiation of a Hematitic-Goethitic Taconite. BuMines RI 8459, 1981, 15 pp.

Placek, P. L., and D. A. Elkins. A Computer Program To Estimate Costs for Process Evaluation. BuMines OFR 95-81, March 1981, 233 pp.

Placek, P. L., A. G. Lawerence, I. L. Nichols, and D. C. Seidel. Feed Grade Versus Extraction Correlation on Uranium Ores From New Mexico. BuMines RI 8528, 1981, 52 pp.

Pool, D. L., B. J. Scheiner, and S. D. Hill. Recovery of Metal Values From Lead Smelter Matte by Chlorine-Oxygen Leaching. BuMines RI 8615, 1982, 19 pp.

Rabb, D. D. Recovery of Metal Values Prior to Reclamation of Mined Areas in the Southwest. BuMines OFR 109-81, June 30, 1980, 49 pp.; NTIS, PB 81-236796.

Raddatz, A. E., J. M. Gomes, and M. M. Wong. Laboratory Investigation of Sulfurous Acid Leaching of Kaolin for Preparing Alumina. BuMines RI 8533, 1981, 15 pp.

———. Laboratory Investigation of Sulfurous Acid Leaching of Kaolin for Preparing Alumina. Pres. at AIME Ann. Meeting, Chicago, Ill., Feb. 23-27, 1981, TMS Paper Selection A81-41, 15 pp.

Richardson, P. E., G. R. Hyde, and M. S. Ojalvo. The Physical Chemistry of Mineral-Reagent Interactions of Sulfide Flotation. Proceedings of Symposium Held at College Park, Md., Apr. 6-7, 1978. BuMines IC 8818, 1980, 171 pp.

Riley, W. D., R. P. Walters, F. X. McCawley, G. R. Conner, and P. B. Needham, Jr. Well Engineering and Sampling Variables in the Evaluation of Geobrines. BuMines RI 8465, 1980, 20 pp.

Rogers, D. T., and R. T. Sorensen, Jr. Computer Simulation Applied to the Separation of Porous Leach Residue Solids From Liquor by Horizontal Belt Filtration. BuMines IC 8873, 1982, 27 pp.

Salisbury, H. B., M. L. Wouden, and M. B. Shirts. Beneficiation of Low-Grade California Chromite Ores. BuMines RI 8592, 1982, 15 pp.

Scalera, J. V. The Determination of Chrysotile in Insulation Samples Using Combined TGA-GCA. Proc. North. Am. Thermal Analysis Soc. Conf., New Orleans, La., Oct. 19-21, 1981, v. 2, No. 5, pp. 303-309.

Schaefer, S. C. Electrochemical Determination of Gibbs Energies of Formation of Cobalt and Nickel Sulfides. BuMines RI 8588, 1981, 18 pp.

———. Electrochemical Determination of Gibbs Energies of Formation of MnS and $Fe_{0.9}S$. BuMines RI 8486, 1980, 17 pp.

———. Electrochemical Determination of Gibbs Energies of Formation of MoS_2 and WS_2. BuMines RI 8405, 1980, 17 pp.

Schaefer, S. C., and N. A. Gokcen. Electrochemical Determination of Thermodynamic Properties of Molybdenite (MoS). High Temp. Sci., v. 12, 1980, pp. 267-276.

———. Thermodynamic Properties of Ferrous and Ferric Fluoride by Electromotive Force Measurements. High Temp. Sci., v. 14, 1981, pp. 153-159.

Scheiner, B. J., and D. L. Pool. Recovery of Molybdenum and Rhenium From Concentrates by an Electrooxidation-Solvent Extraction—Carbon Adsorption Technique. Pres. at Internat. Cong., Inst. Min. Eng., Santiago, Chile, Nov. 23-29, 1980; Anales Congr. Cincuentenario Min. Cobres Porfidicos, v. 2, pp. 122-148.

Schiller, J. E., and S. E. Khalafalla. Contact Filtration of Asbestos Fibers With Magnesium Oxide. Pres. at 109th AIME Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980, SME Preprint 80-108, 17 pp.

Schiller, J. E., and S. L. Payne. Microelectrophoresis of Asbestos Fibers. Comparison of Theory With Experimental Data. J. Phys. Chem., ACS, v. 85, 1981, p. 2438.

———. Surface Charge Measurements of Amphibole Cleavage Fragments and Fibers. BuMines RI 8483, 1980, 23 pp.

Schluter, R. B. Separation of Copper-Nickel Mattes From Duluth Gabbro Concentrates by Flotation and Magnetic Methods. BuMines RI 8646, 1982, 14 pp.

Schluter, R. B., and W. M. Mahan. Flotation Responses of Two Duluth Complex Copper-Nickel Ores. BuMines RI 8509, 1981, 24 pp.

Schultze, L. E., and D. J. Bauer. Operation of a Mineral Recovery Unit on Brine From the Salton Sea Known Geothermal Resource Area. BuMines RI 8680, 1982, 12 pp.

Schultze, L. E., D. J. Bauer, and M. T. Morimoto. Extracting Uranium From Carbonaceous Ores. BuMines RI 8580, 1981, 12 pp.

Shamsudden, M., and M. E. Wadsworth. Uranium-Phosphorus Chemistry and Extraction of Uranium From Uraniferous Phosphorites. BuMines OFR 99-80, Mar. 31, 1980, 83 pp.; NTIS, PB 80-229008.

Shanks, D. E., J. A. Eisele, and D. J. Bauer. Hydrogen Chloride Sparging Crystallization of Aluminum Chloride Hexahydrate. BuMines RI 8593, 1981, 15 pp.

Shanks, D. E., J. A. Eisele, and D. J. Bauer. Recovery of Aluminum Hydroxy Sulfate From Aluminum Sulfate Solution by High-Temperature Hydrolysis. BuMines RI 8550, 1981, 10 pp.

Shedd, K. B., R. L. Virta, and A. G. Wylie. Size and Shape Characterization of Fibrous Zeolites by Electron Microscopy. BuMines RI 8674, 1982, 30 pp.

Sjoberg, J., and J. M. Gomes. Platinum-Group Minerals in Alluvial Deposits. Pres. at Precious Metals Conf., Sparks,

Nev., Nov. 17-20, 1980; pub. in California Geol., v. 34, No. 5, May 1981, pp. 91-98.

Smith, R. W. Fundamentals of Chromite Flotation. BuMines OFR 45-82, June 30, 1981, 57 pp.; NTIS, PB 82-197492.

Smith, G. E., J. L. Hulatt, and M. B. Shirts. Amine Flotation of Chromite Ores From the Stillwater Complex, Mont. BuMines RI 8502, 1981, 12 pp.

Smith, C. W., C. E. Jordan, and G. V. Sullivan. Crushing Techniques for Pneumatic Concentration of Mica. BuMines RI 8601, 1982, 16 pp.

Sorensen, R. T., E. B. Amey III, and D. L. Sawyer. The Removal of Iron From Aluminum Chloride Leach Liquor by Solvent Extraction. BuMines RI 8560, 1981, 28 pp.

Spironello, V. R., and W. M. Mahan. Partial Replacement of Coke in Cupola Operation. BuMines RI 8488, 1980, 19 pp.

Steel, E. B. Optical Microscopy of Particles. Characterization of Particles, ed. by K. F. J. Heinrich. NBS Spec. Pub. 533, April 1980, pp. 5-11.

Stanczyk, M. H., and I. L. Feld. Comminution by the Attrition Grinding Process. BuMines Bull. 670, 1980, 43 pp.

Stanley, D. A., P. M. Brown, and B. J. Scheiner. The Determination of the Points of Zero Charge of Fine Mineral Particles by a Titration Technique. BuMines RI 8635, 1982, 7 pp.

Stuve, J. M., and M. J. Ferrante. Low-Temperature Heat Capacities and High-Temperature Enthalpies of Chiolite ($Na_5Al_3F_{14}$). BuMines RI 8442, 1980, 8 pp.

Stuve, J. M., M. J. Ferrante, D. W. Richardson, and R. R. Brown. Thermodynamics Properties of Ferric Oxychloride and Low-Temperature Heat Capacity of Ferric Trichloride. BuMines RI 8420, 1980, 14 pp.

Termes, S. C., R. L. Wilfong, and P. E. Richardson. Insoluble Crosslinked Starch Xanthate as a Selective Flocculant for Sulfide Minerals. Pres. at 111th SME-AIME Ann. Meeting, Dallas, Tex., Feb. 14-18, 1982, SME Preprint 82-171, 8 pp.

Thompson, P., and J. L. Hulatt. Development of a Continuous Flotation Process for Removal of Insoluble Slimes From Potash Ore. BuMines RI 8516, 1981, 21 pp.

Tisdel, L. C., A. G. Melcher, and G. M. Hermsen. Evaluation of Environmental Factors Involved in Metallurgical Processes To Utilize Domestic Resources for Production of Alumina. Phase III Report: Environmental Impact Criteria for Evaluating Potential Pilot Plant Sites: Clay-Hydrochloric Acid Extraction-Gas Induced Crystallization Process. BuMines OFR 165(2)-81, March 1981, 50 pp.; NTIS, PB 82-138272.

Tisdel, L. C., W. J. Roushey, A. G. Melcher, F. T. Davis, J. M. Link, and R. C. Barth. Evaluation of Environmental Factors Involved in Metallurgical Processes To Utilize Domestic Resources for Production of Alumina. Phase II Report: Assessment of Two Raw Material/Process Technology Options. BuMines OFR 165(1)-81, December 1979, 121 pp.; NTIS, PB 82-138264.

UOP Inc., Mineral Sciences Div. New Procedure for Recovering Nickel and Cobalt From Western Laterites. Economic Feasibility. BuMines OFR 68-82, January 1982, 167 pp.

Virta, R. L., K. B. Shedd, and W. J. Campbell. Identification and Quantification of Asbestos in Construction Materials Using Polarized Light Microscopy: The Need for Standards. Proc. NBS/EPA Asbestos Standards Workshop, Gaithersburg, Md., Oct. 1-3, 1980, ed. by J. Small and E. Steel; NBS SP 619, March 1982, pp. 34-43.

White, J. C., J. L. Henry, and C. J. Krogh. Removal of Organic Contaminants From Aluminum Chloride Solutions. BuMines RI 8619, 1982, 17 pp.

Wong, M. M., F. P. Haver, and R. G. Sandberg. Ferric Chloride Leach-Electrolysis Process for Production of Lead. Proc. 1980 World Lead-Zinc Symp., Las Vegas, Nev., Mar. 27-29, 1980, pp. 445-454.

Woodbury, F. B. W. Application of Thermal Neutron Capture-Gamma Ray Analysis to Oxidized Taconite Beneficiation Process Slurries. BuMines RI 8460, 1980, 71 pp.

———. Monitoring Taconite Process Streams With Thermal Neutron Capture-Gamma Ray Analysis. BuMines RI 8461, 1980, 24 pp.

Wylie, A. G., and C. W. Huggins. Characteristics of a Potassium Winchite-Asbestos From the Allamoore Talc District, Texas. Can. Mineral., v. 18, February 1980, pp. 101-107.

Wylie, A. G., and P. Schweitzer. The Effects of Sample Preparation and Measuring Techniques on the Shape and Shape Characterization of Mineral Particles: The Case of Wollastonite. Env. Res., v. 27, 1982, pp. 52-73.

Wylie, A. G., K. Shedd, and M. E. Taylor. Volume Measurements of Asbestos in the SEM. Univ. Md. Inst. for Phys. Sci. and Technol., Electron Microscope Central Facility Newsletter, ed by M. E. Taylor, No. 10, March 1982, pp. 18-19.

Young, W. A., G. M. Pugh, G. D. Vandersluis, and V. Lim. Improved Ore Recovery From Phosphate Open-Pits in the Phosphoria Formation. BuMines OFR 1-81, March 1980, 314 pp.; NTIS, PB 81-167512.

Materials and Recycling Technology

Ackman, T. E. Sludge Disposal From Acid Mine Drainage Treatment. BuMines RI 8672, 1982, 25 pp.

Ambrose, F., and B. W. Dunning, Jr. Mechanical Processing of Electronic Scrap to Recover Precious-Metal-Bearing Concentrates. Precious Metals, ed. by R. O. McGachie and A. G. Bradley. Pergamon Press, Toronto, Can., 1980, pp. 67-76.

———. Precious Metals Recovery From Electronic Scrap. Proc. 7th Miner. Waste Utilization Symp., Chicago, Ill., Oct. 20-21, 1980, sponsored by the U.S. Bureau of Mines and IIT Research Institute, October 1980, pp. 184-197.

Anable, W. E., J. I. Paige, and D. L. Paulson. Copper Recovery From Primary Smelter Dusts. BuMines RI 8554, 1981, 19 pp.

Atkinson, G. B., L. J. Nicks, E. G. Baglin, and D. J. Bauer. Hydrogenation Catalysts From Intermetallic Compounds. BuMines RI 8631, 1982, 8 pp.

Beard, H. R., H. B. Salisbury, and M. B. Shirts. Absorption of Radium and Thorium From New Mexico Uranium Mill Tailing Solutions. BuMines RI 8463, 1980, 14 pp.

Bennett, J. P. Corrosion Resistance of Ceramic Materials to Hydrochloric Acid (20 Wt-Pct at 50° C). BuMines RI 8650, 1982, 11 pp.

Benzel, J., J. Cochran, R. Kolarik, K. Lee, E. McGee, and L. Smith. Calcia Stabilized Zirconia Castable. BuMines OFR 65-81, June 1980, 112 pp.; NTIS, PB 81-214819.

Blickensderfer, R. Cladding Metals by Continuous Strip Rolling in Vacuum. BuMines RI 8495, 1980, 11 pp.

——— Cladding of Metals to Iron by Vacuum Rolling. BuMines RI 8481, 1980, 25 pp.

Bloom, P. A., J. H. Maysilles, and H. Doiesal. Hydrometallurgical Treatment of Arsenic-Containing Lead-Smelter Flue Dust. BuMines 8679, 1982, 12 pp.

Bortz, S. A., and R. S. DeCesare (comp.). Accomplishments in Waste Utilization. A Summary of the Seventh Mineral Waste Utilization Symposium. BuMines IC 8884, 1982, 88 pp.

Bortz, S. A., and K. B. Highie (comp.). Materials Recycling. An Overview of the Sixth Mineral Waste Utilization Symposium. BuMines IC 8826, 1980, 157 pp.

Brandt, L. W. Dewatering Florida Phosphatic Clay Wastes With Moving Screens. BuMines RI 8529, 1981, 16 pp.

Brierley, C. L., G. R. Lanza, and B. Schreiner. Microbial Processes for Removal of Suspended Clays From Selected Industrial Wastewaters. Biotechnology and Bioengineering Symp. John Wiley & Sons, Inc., New York, No. 11, 1981, pp. 507-520.

Bremner, P. R. Silver Recovery From Cyanide Tailings Using an Acidic NaCl-$FeCl_3$ Leachant. BuMines RI 8649, 1982, 7 pp.

Burrus, J. M., and R. K. Koch. Sandcasting Titanium and Zirconium. Foundry Management and Tech., v. 110, No. 5, May 1982, pp. 43-51.

Calvert, E. D. An Investment Mold for Titanium Casting. BuMines RI 8541, 1981, 35 pp.

Calvert, E. D., and H. W. Leavenworth, Jr. Zirconium Oxide Molds for Small Molybdenum Investment Castings. BuMines RI 8624, 1982, 26 pp.

Campbell, A. B., III, B. D. Sartwell, and P. B. Needham, Jr. Depth Profiling of Ion-Implanted Alloys. J. Appl. Phys., v. 51, No. 1, January 1980, pp. 283-289.

Carnahan, T. G., and M. A. Lucas. Weathering of a Base-Metal Sulfide Leaching Residue. BuMines RI 8667, 1982, 11 pp.

Carter, J. P., and S. D. Cramer. Field Stress Corrosion Tests in Brine Environments of the Salton Sea Known Geothermal Resource Area. Mater. Performance, v. 19, No. 9, 1980, pp. 13-16.

Carter, J. P., S. D. Cramer, and R. K. Conrad. Corrosion of Stainless Steels in the Geothermal Environments of the Salton Sea Known Geothermal Resources Area. Nat. Assoc. Corrosion Eng., Corrosion/81, Preprint 230, 15 pp.

——— An Overview of Materials and Corrosion in Geothermal Systems. Pres. at Energy-Sources Technol. Conf. Exhibition, New Orleans, La., Feb. 3-7, 1980 (pub. in Materials and Corrosion Problems in Energy Systems, ed. by W. J. Lochmann and M. Indig). National Association of Corrosion Engineers, Houston, Tex., pp. 17-1—17-10.

Carter, J. P., and F. X. McCawley. Corrosion Tests in Brine and Steam From the Salton Sea KGRA. J. Mater. for Energy Systems, v. 3, No. 4, March 1982, pp. 30-38.

Chambers, D. H., and B. W. Dunning, Jr. Silver Recovery From Aircraft Scrap. BuMines RI 8477, 1980, 23 pp.

Clancy, T. A. High-Temperature Corrosion Resistance of Ceramic Materials. BuMines IC 8843, 1981, 31 pp.

Cobble, J. R., and L. Y. Sadler III. A Laboratory Test To Evaluate the Resistance of Refractories to Molten Slags. BuMines RI 8468, 1980, 13 pp.

Cole, E. R., Jr., A. Y. Lee, and D. L. Paulson. Electrolytic Method for Recovery of Lead From Scrap Batteries. BuMines RI 8602, 1981, 19 pp.

Covino, B. S., Jr., J. P. Carter, and S. D. Cramer. The Corrosion Behavior of Niobium in Hydrochloric Acid Solutions. Corrosion, v. 36, No. 10, October 1980, pp. 554-558.

Covino, B. S., Jr., M. Rosen, and W. D. Riley. Corrosion Resistance of Materials in the Aqueous Hydrochloric Acid Environments Associated With the Recovery of Aluminum From Kaolinitic Clays. BuMines RI 8565, 1981, 28 pp.

Covino, B. S., Jr., B. D. Sartwell, G. R. Conner, and P. B. Needham, Jr. Electrochemical Corrosion Behavior of Alloys Formed by Ion Implantation. BuMines RI 8431, 1980, 20 pp.

Crane, S. R., L. Crocker, and W. I. Nissen. Hydrogen Sulfide Generation by Reaction of Natural Gas, Sulfur, and Steam. BuMines RI 8539, 1981, 54 pp.

Cramer, S. D. The Solubility of Oxygen in Brines From 0 to 300° C. I&EC Process Des. & Develop., April 1980, v. 19, No. 2, pp. 300-305.

Cramer, S. D., and J. P. Carter. Corrosion in Geothermal Brines of the Salton Sea Known Geothermal Resource Area. Geothermal Scaling and Corrosion, ed. by L. A. Casper and T. R. Pinchback, ASTM STP 717, 1980, pp. 113-141.

——— Laboratory Corrosion Studies in Low- and High-Salinity Geobrines of the Imperial Valley, Calif. BuMines RI 8415, 1980, 30 pp.

Cramer, S. D., J. P. Carter, and B. S. Covino, Jr. Atmosphere Corrosion Resistance of Steels Prepared From the Magnetic Fraction of Urban Refuse. BuMines RI 8447, 1980, 32 pp.

Curwick, L. R., W. A. Peterson, and H. V. Makar. Availability of Critical Scrap Metals Containing Chromium in the United States. Superalloys and Cast Heat- and Corrosion-Resistant Alloys. BuMines IC 8821, 1980, 51 pp.

——— Availability of Critical Scrap Metals Containing Chromium in the United States. Part 1. Superalloys and Cast Heat and Corrosion-Resistant Alloys. BuMines OFR 8(1)-80, 1979, 114 pp.

Dannenberg, R. O., A. E. Petersen, P. B. Altringer, and P. T. Brooks. Molybdenum Removal From Concentrator Waste Water. BuMines RI 8686, 1982, 16 pp.

Davis, E. G., and G. V. Sullivan. Ceramic Mold Inserts for Use in Ferrous Diecasting. BuMines RI 8557, 1981, 27 pp.

deBarbadillo, J. J., J. K. Pargeter, and H. V. Makar. Process for Recovering Chromium and Other Metals From Superalloys Scrap. BuMines OFR 69-80, Apr. 15, 1980, 156 pp.

——— Process for Recovering Chromium and Other Metals From Superalloy Scrap. BuMines RI 8570, 1981, 73 pp.

DeCesare, R. S., F. J. Palumbo, and P. M. Sullivan. Pilot-Scale Studies on the Composition and Characteristics of Urban Refuse. BuMines RI 8429, 1980, 32 pp.

Driscoll, T. J. The Initial Oxidation of Iron at 200° and 300° C and the Effect of Surface Sulfur. J. Oxidation Metal, v. 16, No. 1/2, 1981, pp. 197-131.

Dunning, J. S. An Iron-Aluminum-Molybdenum Alloy as a Chromium-Free Stainless Steel Substitute. BuMines RI 8654, 1982, 13 pp.

——— Iron-Based Alloys Strengthened by Ternary Laves Phases. BuMines RI 8411, 1980, 13 pp.

Dunning, B. W., Jr., and F. Ambrose. Characterization of Pre-1957 Avionic Scrap for Resource Recovery. BuMines RI 8499, 1980, 20 pp.

Dunning, J. S., M. L. Glenn, and W. L. O'Brien. Iron-Base Alloys Strengthened by Laves Phases as Substitutes for Stainless Steels. BuMines RI 8470, 1980, 24 pp.

Eddy, W. H., and G. V. Sullivan. Recovery of Potash Feldspar From Molybdenite Tailings. BuMines RI 8475, 1980, 22 pp.

Farley, K. R., K. W. Sheetz, and A. B. Whitehead.

Determination of Antimony in Smelter Flue Dusts by Atomic Absorption Spectrometry. BuMines RI 8510, 1981, 9 pp.

Flinn, D. R., J. A. Kirk, M. J. Lynch, and B. G. Van Stratum. Wear Properties of Electrodeposited Titanium Diboride Coatings. BuMines RI 8537, 1981, 30 pp.

Flinn, D. R., and C. L. Manger. Electrochemical Studies of Platinum-Group Metals in Molten Alkali Cyanides. BuMines RI 8656, 1982, 16 pp.

Floreen, S. Chromium Substitution in Stainless Steels. BuMines OFR 110-81, November 1980, 80 pp.; NTIS, PB 81-235475.

Flynn, C. M., Jr., T. G. Carnahan, and R. E. Lindstrom. Absorption of Heavy Metal Ions by Xanthated Sawdust. BuMines RI 8427, 1980, 12 pp.

Funke, R. H., Jr., and W. C. McBee. An Industrial Application of Sulfur Concrete. Ch. 12 in Sulfur: New Sources and Uses, ed. by M. E. D. Raymont. ACS Symp. Series 183, 1982, pp. 195-208.

George, L. C., D. M. Soboroff, and A. A. Cochran. Regeneration of Waste Chromic Acid Etching Solutions in an Industrial-Scale Research Unit. Proc. 3d EPA/AES Conf., Advancing Pollution Control for the Metal Finishing Ind., Kissimmee, Fla., Apr. 14-16, 1980, pp. 33-36.

Gomes, J. M., G. M. Martinez, and M. M. Wong. Recovery of Byproduct Heavy Minerals From Sand and Gravel Operations in Central and Southern California. BuMines RI 8471, 1980, 20 pp.

———. Recovery of Byproduct Heavy Minerals From Sand and Gravel Operations in Central and Southern California. Proc. Mineral Resource Potential of California Conf., Sacramento, Mar. 27-28, 1980, pp. 54-70.

Hagni, R. D., and M. Cooper. Characterization of Accessory Minerals in the Birmingham Red Iron Ores and Eufaula Ferruginous Bauxite Deposits in Alabama. BuMines OFR 23-82, Mar. 29, 1981, 127 pp.; NTIS, PB 82-183369.

Haynes, B. W., G. W. Kramer, R. C. Gabler, Jr., and R. L. Stoll. Resource and Environmental Assessment of Large-Volume Wastes: Cement Kiln Dust, Phosphate Rock Wastes, and Coal Ash. Industrial Waste, Proc. 14th Mid-Atlantic Ind. Waste Conf., June 27-29, 1982, College Park, Md., ed. by J. E. Alleman and J. T. Kavonagh, pp. 222-231.

Haynes, B. W., G. W. Kramer, and J. A. Jolly. Fluorine and Uranium in Phosphate Rock Processing and Waste Materials. BuMines RI 8576, 1981, 17 pp.

Haynes, B. W., S. L. Law, and J. A. Jolly. Eastern Cement Kiln Dust Characterization. Pres. at AIME Ann. Meeting, Chicago, Ill., Feb. 23-27, 1981. TMS Paper Selection A81-39, February 1981, 10 pp.

Haynes, B. W., J. Zabronsky, and D. L. Naylan. A Resin Loaded Paper X-Ray Fluorescence Method for Determining Uranium in Phosphate Materials. Proc. 30th Ann. Conf. Applications of X-Ray Analysis, Denver, Colo., Aug. 3-7, 1981, pub. as Advances in X-Ray Analysis, Plenum Press, N. Y., v. 25, pp. 107-111.

Hebble, T. L., V. R. Miller, and D. L. Paulson. Recovery of Principal Metal Values From Electrolytic Zinc Waste. BuMines RI 8582, 1981, 12 pp.

Hearie, T. A. Gearing Up To Control Trace Elements During Mineral Processing. Min. Cong. J., v. 66, No. 4, April 1980, pp. 18-20.

Heystek, H., and N. S. Raymon. Testing and Development of Materials for Catalytic Coal Gasification Process Equipment. Proc. 5th Ann. Conf. on Materials for Coal Conversion and Utilization, Gaithersburg, Md., Oct. 7-9, 1980, pp. IV-1—IV-7.

Horter, G. L., and L. C. George. Demonstration of Technology To Recycle Chromic Acid Etchants at Gould, Inc. Proc. 4th Recycling World Cong. and Exposition, New Orleans, La., Apr. 5-7, 1982, pp. M/3/5/1—M/3/5/13.

Johnson, E. Q., L. L. Oden, and P. E. Sanker. Results of EPA Extraction Procedure Toxicity Test Applied to Copper Reverberatory Slags. BuMines RI 8648, 1982, 16 pp.

Johnson, E. A., P. E. Sanker, L. L. Oden, and J. B. See. Copper Losses and the Distribution of Impurity Elements Between Matte and Silica-Saturated Iron Silicate Slags at 1,250° C. BuMines RI 8655, 1982, 18 pp.

Jong, B. W. Effect of Additives on Sintering of Silicon Nitride-Alumina Compositions. BuMines RI 8466, 1980, 16 pp.

Jong, B. W., and H. Heystek. Effect of Additives on Sintering of Silicon Nitride-Alumina-Aluminum Nitride Compositions. BuMines RI 8546, 1981, 14 pp.

Kalyoncu, R. S. Chemically Bonded Refractories—A Review of the State of the Art. BuMines IC 8878, 1982, 20 pp.

Kilau, H. W., V. R. Spiromilio, I. D. Shah, and W. M. Mahan. Evaluation of Synthetic Fluorspar in BOF Slags. BuMines RI 8558, 1981, 28 pp.

Kirk, J. A., D. E. Flinn, and M. J. Lynch. Wear of TiB$_2$ Coatings. J. Wear, v. 72, December 1981, pp. 315-323.

Koch, R. K., and J. M. Burrus. Bentonite-Bonded Rammed Olivine and Zircon Molds for Titanium Casting. BuMines RI 8587, 1981, 40 pp.

———. Shape-Casting Titanium in Olivine, Garnet, Chromite, and Zircon Rammed and Shell Molds. BuMines RI 8443, 1980, 33 pp.

Kramer, G. W., and B. W. Haynes. Anion Characterization of Florida Phosphate Rock Mining Materials and U.S. Cement Kiln Dust by Ion Chromatography. BuMines RI 8661, 1982, 8 pp.

Kusik, C. L., H. V. Makar, and M. R. Mounier. Availability of Critical Scrap Metals Containing Chromium in the United States. Part 2. Wrought Stainless Steel and Heat-Resisting Alloys. BuMines OFR 8(2)-80, 1979, 83 pp.

———. Availability of Critical Scrap Metals Containing Chromium in the United States. Wrought Stainless Steels and Heat-Resisting Alloys. BuMines IC 8822, 1980, 31 pp.

Kusik, C. L., K. Parameswaran, D. J. Kinneberg, and H. V. Makar. Chromium Recovery From Scrap: An Experimental Program. Proc. AIME Symp., Extractive Metallurgy of Refractory Metals, Chicago, Ill., Feb. 2-26, 1981, pp. 419-436.

———. Pyrometallurgical Recovery of Chromium From Scrap Metals: Laboratory Studies. BuMines RI 8571, 1981, 41 pp.

———. Pyrometallurgical Recovery of Chromium From Scrap Metals: Laboratory Studies and Pilot Plant Design. BuMines OFR 75-80, February 1980, 68 pp.

Lamont, W. E., E. G. Davis, and G. V. Sullivan. Retreatment of Tailings To Recover Barite. Proc. 7th Miner. Waste Utilization Symp., Chicago, Ill., Oct. 20-21, 1980, sponsored by U. S. Bureau of Mines and IIT Research Institute, pp. 26-33.

Lamont, W. E., and G. V. Sullivan. Recovery of High-Grade Barite From Waste Pond Materials. BuMines RI 8673, 1982, 13 pp.

———. Recovery of Ultrafine Barite From Mill Wastes. BuMines RI 8668, 1982, 12 pp.

Landsberg, A., J. E. Mausey, and J. L. Henry. Behavior of Arsenic in a Static Bed During Roasting of Copper Smelter Feed. BuMines RI 8693, 1980, 18 pp.

Law, S. L. Industrial Wastes. McGraw-Hill Encyclopedia of Environmental Science, ed by S. P. Parker, McGraw-Hill Book Co., Inc., New York, 2d ed., 1980, pp. 387-396.

Law, S. L., B. W. Haynes, and W. J. Campbell. Development of Analytical Reference Material for Refuse-Derived Fuels. BuMines RI 8426, 1980, 11 pp.

Lien, R. H., D. A. Martin, and W. I. Nissen. Description and Economic Evaluation of Flue Gas Desulfurization by the Modified Citrate Process. BuMines RI 8638, 1982, 26 pp.

Liles, K. J., and H. Heystek. Evaluating Clay Resources From Clay County, Ga., for Structural Clay Products. BuMines RI 8421, 1980, 28 pp.

Lincoln, R. L., and R. Blickensderfer. Adapting Conventional Sputtering Equipment for Coating Long Tubes and Strips. J. Vac. Sci. Technol., v. 17, No. 5, September-October 1980, pp. 1252-1253.

Llewellyn, T. O., and G. V. Sullivan. Recovery of Rutile From a Porphyry Copper Tailings Sample. BuMines RI 8462, 1980, 18 pp.

Madsen, B. W., H. Dolezal, and P. A. Bloom. Processing Arsenical Flue Dusts With Sulfur Dioxide and Sulfuric Acid to Produce Arsenic Trioxide. Pres. at TMS-AIME Ann. Meeting, Chicago, Ill., Feb. 22-26, 1981, 13 pp.

Madsen, B. W., and R. D. Groves. Alternative Methods for Copper Recovery From Dump Leach Liquors. BuMines RI 8520, 1981, 17 pp.

Magyar, M. J., R. S. Kaplan, and H. V. Makar. Experimental Processing of Salt Slags From an Aluminum Dross Furnace. BuMines RI 8446, 1980, 26 pp.

Marchant, W. N., S. L. May, B. W. Moore, and W. W. Simpson. The Chemical Reactions of Sulfur in the Citrate Process for Flue Gas Desulfurization. BuMines RI 8540, 1981, 23 pp.

Marchant, W. N., S. L. May, W. W. Simpson, J. K. Winter, and H. R. Beard. Analytical Chemistry of the Citrate Process for Flue Gas Desulfurization. BuMines IC 8819, 1980, 20 pp.

Marchant, J. D., E. Morrice, B. P. Herve, and M. M. Wong. Preparing Rare Earth-Silicon-Iron-Aluminum Alloys. BuMines RI 8445, 1980, 10 pp.

Martinez, G. M., J. M. Gomes, and M. M. Wong. Recovery of Byproduct Heavy Minerals From Sand and Gravel Operations in Oregon and Washington. BuMines RI 8563, 1981, 14 pp.

Martin, E., and A. V. Petty, Jr. Recycling Spent Chrome Refractories From Steelmaking Furnaces. BuMines RI 8489, 1980, 12 pp.

_____. Recycling of Waste Magnesite-Chrome Refractories. Pres. at TMS-AIME Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980; TMS Paper Selection A80-40, March 1980, 15 pp.

Matthes, S. A. Rapid, Low-Cost Analysis of a Copper Slag for 13 Elements by Flame Atomic Absorption Spectroscopy. BuMines RI 8484, 1980, 8 pp.

May, A., and J. W. Sweeney. Assessment of Environmental Impacts Associated With Phosphogypsum in Florida. BuMines RI 8639, 1982, 19 pp.

_____. Assessment of Toxicity Impacts Associated With Phosphogypsum in Florida. Proc. Environmental Symp. '82, sponsored by the Fertilizer Inst., San Antonio, Tex., Mar. 8-10, 1982, pp. 97-121.

McBee, W. C., P. A. Romans, T. A. Sullivan, and R. R. Uhde. Sulphur Research and Development—Role of Sulphur in SEA Pavements. Sulphur Res. and Developments, v. 4, 1981, pp. 5-12.

_____. The Role of Sulphur in Sulphur Extended Asphalt Pavements. Proc. Sulphur-81, Internat. Conf. on Sulphur, Calgary, Alberta, Canada, May 25-28, 1981, pp. 347-365.

McBee, W. C., T. A. Sullivan, and B. W. Jong. Modified-Sulfur Cements for Use in Concretes. BuMines RI 8545, 1981, 24 pp.

_____. Modified-Sulphur Concrete Technology. Proc. Sulphur-81, Internat. Conf. on Sulphur, Calgary, Alberta, Canada, May 25-28, 1981, pp. 367-388.

McBee, W. C., T. A. Sullivan, and D. Saylak. An Overview of Sulfur-Extended Asphalt Usage. Pres. at FAA Eastern Region Airport Eng. Seminar, Hershey, Pa., Mar. 3, 1980; pub. in Asphalt Pavement Construction: New Materials and Techniques, ed. by J. A. Scherocman, ASTM STP 724, pp. 39-63.

McCawley, F. X., S. D. Cramer, W. D. Riley, J. P. Carter, and P. B. Needham, Jr. Corrosion of Materials and Scaling in Low-Salinity East Mesa Geothermal Brines. BuMines RI 8504, 1981, 17 pp.

McDonald, H. O., D. M. Soboroff, and A. A. Cochran. Electrolytic Reduction of Chromium (VI) and Copper Using Coke Electrodes. BuMines RI 8472, 1980, 8 pp.

McIlwain, J. F., and L. A. Neumeier. Consolidation of an Iron-Base Superalloy by Powder Metallurgy Techniques. BuMines RI 8556, 1981, 22 pp.

Miller, V. R., T. L. Hebble, and D. L. Paulson. Recovery of Cadmium, Zinc, and Lead From Lead Smelter Flue Dusts. BuMines RI 8659, 1982, 12 pp.

Neumann, J. P. On the Occurrence of Substitutional and Triple Defects in Intermetallic Phases With the B2 Structure. Acta Metallurgica, v. 28, 1980, pp. 1165-1170.

Neumeier, L. A., B. A. Betts, and R. L. Crosby. Experiments in Hot-Rolling and Forging of Ductile Cast Iron. BuMines RI 8448, 1980, 36 pp.

Oden, L. L., M. P. Krug, and R. A. McCune. Analysis of Vapor-Aluminum-Diffused Stainless Steels. BuMines RI 8629, 1982, 12 pp.

Pahlman, J. E., C. F. Anderson, and S. E. Khalafalla. High-Temperature Corrosion Resistance of Alumina Refractories to Lignite Ash Slags. BuMines RI 8430, 1980, 20 pp.

_____. High-Temperature Corrosion Resistance of Basic Refractories to Coal and Lignite Ash Slags. BuMines RI 8633, 1982, 11 pp.

Pahlman, J. E., M. L. Boucher, S. L. Payne, and S. E. Khalafalla. Method for Preparing Ferrochromium Alloys by Vacuum Reduction and Simple Melting of Reduced Products. Bumines RI 8514, 1981, 22 pp.

Paulson, D. L., W. M. Dressel, and R. M. Doerr. Cobalt and Nickel Recovery From Missouri Lead Ores. Proc. 7th Miner. Waste Utilization Symp., Chicago, Ill., Oct. 20-21, 1980, pp. 127-134.

Petty, A. V., Jr. Refractory Properties of Brick Produced From Beneficiated Chrome-Containing Furnace Linings. BuMines RI 8685, 1982, 16 pp.

Petty, A. V., Jr., and E. Martin. Recycling of Waste Magnesite-Chrome Refractories From Copper Smelting Furnaces. BuMines RI 8589, 1981, 18 pp.

Pickel, R. L., P. J. Barrett, and D. M. Starrett. Sand Bed Dewatering of Alumina Miniplant Tailings. BuMines RI 8677, 1982, 10 pp.

Rieber, M., J. M. Barker, and M. Worrall. Sulfur Pollution Control. Phase II. The Impact of Stack Gas Cleanup on the Sulfur Mining Industry of Texas and Louisiana. BuMines OFR 94(4)-81, January 1981, 114 pp.; NTIS, PB 81-222820.

Rieber, M., R. Fuller, and O. Dellaretti. Sulfur Pollution Control. Phase I. The Disposal Program (Sections 5 Through 7). BuMines OFR 94(2)-81, January 1981, 189 pp.; NTIS, PB 81-222804.

Rieber, M., R. Fuller, and B. Okech. Sulfur Pollution Control. Phase I. The Disposal Program (Sections 1 Through 4). BuMines OFR 94(1)-81, January 1981, 362 pp.; NTIS, PB 81-222796.

Rieber, M., B. Okech, and R. Fuller. Sulfur Pollution Control. Phase I. The Disposal Program (Sections 8 and 9). BuMines OFR 94(3)-81, January 1981, 262 pp.; NTIS, PB 81-222812.

Riley, W. D., and B. S. Covino, Jr. Effect of Ferric Ion on Corrosion Resistance of Zirconium in HCl-$AlCl_3$ Environment. BuMines RI 8610, 1982, 15 pp.

Rosen, M. Electrochemical Corrosion of Iron-Chromium Alloys Under Ultra-High-Purity Conditions. BuMines RI 8425, 1980, 66 pp.

Roy, D. M., R. Roy, and T. P. O'Holleran. Innovative Technology for Fabrication of Ceramics: EDS Rapid Solidification Process Application to Specialized Materials. BuMines OFR 66-81, Nov. 15, 1980, 52 pp.; NTIS, PB 81-214868.

Russell, J. H., L. L. Oden, and J. L. Henry. Effects of Additives on Methanation Activity of Raney Nickel Catalysts. BuMines RI 8487, 1980, 21 pp.

Sadler, L. Y., III, N. S. Raymon, K. H. Ivey, and H. Heystek. Effects of High Pressure, High Temperature Steam-Containing Environments on Alumina Refractory Concretes. Am. Ceram. Soc. Bull., v. 60, No. 7. July 1981, pp. 703-706.

Salisbury, H. B., L. J. Duchene, and J. H. Bilbrey, Jr. Recovery of Copper and Associated Precious Metals From Electronic Scrap. BuMines RI 8561, 1981, 16 pp.

Sanders, S. D., E. D. Scott, and G. V. Sullivan. A Rapid-Set Cement Suitable as a Molding Sand Binder for Small Ferrous Castings. BuMines RI 8417, 1980, 16 pp.

Sanker, P. E., R. H. Nafziger, and G. H. Reynolds. Preparation of Specialty Ferrochromium (9 Wt. %C) From a Domestic Chromite. J. Metals, v. 32, No. 1, March 1980, pp. 49-52.

Sartwell, B. D., and A. B. Campell III. Characterization of Thin Films and Solid Surfaces Using Proton-Induced X-Ray Emission. BuMines RI 8455, 1980, 22 pp.

Sartwell, B. D., A. B. Campbell III, B. S. Covino, Jr., and P. B. Needham, Jr. Characterization of Alloys Formed by Ion Implantation. BuMines RI 8434, 1980, 29 pp.

Sartwell, B. D., R. P. Walters, N. S. Wheeler, and C. R. Brown. The Effect of Ion Implanted Alloy Additions on the Linear Polarization and Corrosion Fatigue Behavior of Steel. Proc. Am. Soc. Metals Symp. on Corrosion Resistance of Ion-Implanted and/or Laser-Processing Mater., Fall 1981; pub. in Corrosion and Oxidation of Metals Modified by Directed Energy Beams, ed. by C. R. Clayton and C. M. Preece. The Metallurgical Society of AIME, 1982, pp. 52-72.

Scheiner, B. J., and A. G. Smelley. Dewatering of Thickened Phosphate Clay Waste From Disposal Ponds. Pres. at AIME Ann. Meeting, Chicago, Ill., Feb. 23-27, 1981, TMS Paper Selection A81-6, 9 pp.

———. Water Recovery and Disposal of Clay Waste Slimes. Proc. 1980 Symp. on Surface Mining Hydrology, Sedimentology and Reclamation, Lexington, Ky., Dec. 1-5, 1980, pp. 249-253.

Scheiner, B. J., A. G. Smelley, and D. R. Brooks. Large-Scale Dewatering of Phosphatic Clay Waste From Central Florida. BuMines RI 8611, 1982, 11 pp.

———. Large-Scale Dewatering Tests of Phosphate Clay Waste: Progress Report. Proc. Environmental Symp. '82, sponsored by the Fertilizer Inst., San Antonio, Tex., Mar. 8-10, 1982, pp. 57-70.

Scheiner, B. J., J. R. Zatko, and A. G. Smelley. Consolidation of Industrial Clay Wastes. Proc. Environmental Symp. '80, New Orleans, La., Apr. 7-10, 1980, pp. 477-486.

Smelley, A. G., and B. J. Scheiner. Synergism in Polyethylene Oxide Dewatering of Phosphatic Clay Waste. BuMines RI 8436, 1980, 18 pp.

Smelley, A. G., B. J. Scheiner, and J. R. Zatko. Dewatering of Industrial Clay Wastes. BuMines RI 8498, 1980, 13 pp.

Spironello, V. R., and W. M. Mahan. Utilizing the Magnetic Fraction of Raw Refuse With Shredded Automobile Scrap in Cupola Gray Iron. BuMines RI 8454, 1980, 19 pp.

Spironello, V. R., and R. H. Nafziger. An Evaluation of Used Aluminum Smelter Potlining as a Substitute for Fluorspar in Cupola Ironmelting. BuMines RI 8530, 1981, 14 pp.

Spironello, V. R., I. D. Shah, and R. H. Nafziger. Steels From a Variety of Ferrous Scrap Including Materials of Low Quality. BuMines RI 8622, 1982, 15 pp.

Stanley, D. A., B. J. Scheiner, and Brown. Treatment of Florida Surface Waters for Use in Phosphate Benefication. BuMines RI 8535, 1981, 10 pp.

Stephenson, J. B., E. R. Cole, and D. L. Paulson. Recovery of Zinc From Wastewater Treatment Sludge. Res. and Conservation, v. 6, No. 3-4, November 1981, pp. 203-210.

Stephenson, J. B., and H. O. McDonald. Gasification Pilot Plant Evaluation of CVD Coated Hardware. Proc. 8th Internat. Conf. on Chemical Vapor Deposition, Chantilly-Gouvieux, France, Sept. 15-18, 1981, v. 81-7, November 1981, pp. 642-652.

Sullivan, G. V., and W. E. Lamont. Recovery of Barite From Tailings Ponds and Bypassed Mining Waste. Pres. at SME-AIME, Ann. Meeting, Las Vegas, Nev., Feb. 24-28, 1980, 5 pp.; Min. Eng., v. 33, No. 11, November 1981, pp. 1632-1634.

Sullivan, G. V., and T. O. Llewellyn. Occurrence and Recovery of Rutile From Western Copper Mill Tailings. Pres. at SME-AIME Fall Meeting and Exhibit, Denver, Colo., Nov. 18-20, 1981, SME Preprint 81-333, 7 pp.

Swager, W. L., H. W. Lownie, Jr., and C. E. Mobley. Potential Effect of Ferrous Scrap Composition Changes on the Quality of Iron and Steel Castings. BuMines OFR 37-82, November 1981, 226 pp.; NTIS, PB 82-194184.

Tancous, J. J., and L. C. George. Conservation of Chromium in the Tanning Industry. Proc. 4th Recycling World Cong. and Exposition, New Orleans, La., Apr. 5-7, 1982, pp. M/3/2/1—M/3/2/17.

Tilman, M. M., and L. A. Neumeier. Superplasticity in Commercial and Experimental Compositions of Magnesium Alloy Sheet. BuMines RI 8662, 1982, 29 pp.

University of Arizona, Staff. Sulfur Pollution Control. Phase I. The Disposal Program (Sections 1 Through 9.) Phase II. The Impact of Stack Gas Cleanup on the Sulfur Mining Industry of Texas and Louisiana. BuMines OFR 94(1)—(4)-81, January 1981, 927 pp.; NTIS, PB 81-227788.

U.S. Bureau of Mines. Characterization—Characterization of Bulk Samples. Paper in Characterization, Recovery and Recycling of Electric Arc Furnace Dusts, Lehigh University, Bethlehem, Pa., sec. III, February 1982, pp. III.B-1—III.B-4.

———. Chemical and Physical Separation—Bulk Specimens—Task B—Chemical Extraction. Paper in Characterization, Recovery and Recycling of Electric Arc Furnace Dusts, Lehigh University, Bethlehem, Pa., sec. IV, February 1982, pp. IV.A-1—IV.A-24.

———. Chemical and Physical Separation—Bulk Specimens—Task B—Physical Separation. Paper in Characterization, Recovery and Recycling of Electric Arc Furnace Dusts,

Lehigh University, Bethlehem, Pa., sec. IV, February 1982, pp. IV.C-1—IV.C-13.

Walkiewicz, J. W., J. S. Winston, and M. M. Wong. Magnetic Properties of Alloys Containing Mischmetal, Cobalt, Copper, Iron, and Magnesium. BuMines RI 8583, 1981, 22 pp.

Walters, R. P., N. S. Wheeler, and B. D. Sartwell. The Effects of Surface Modification on the Stress Corrosion Cracking Behavior of 316 Stainless Steel. Corrosion, v. 38, No. 8, August 1982, pp. 437-445.

Wilson, D. A., and H. V. Makar. A Pyrometallurgical Method for Processing Ni-Cd Scrap Batteries. BuMines RI 8574, 1981, 14 pp.

Wittmer, D. E. A Review of Potential Domestic Raw Materials as Substitutes for Refractory-Grade Bauxite. Proc. 111th SME-AIME Ann. Meeting, Dallas, Tex., Feb. 14-18, 1982; pub. in Light Met., 1982, pp. 23-35.

Zatko, J. R. An Environmental Evaluation of Polyethylene Oxide When Used as a Flocculant for Clay Wastes. BuMines RI 8438, 1980, 13 pp.

———. Polymeric Concentration Determined by Drag Reduction. BuMines RI 8559, 1981, 11 pp.

Zatko, J. R., B. J. Scheiner, and A. G. Smelley. Preliminary Studies on the Dewatering of Coal-Clay Waste Slurries Using a Flocculant. BuMines RI 8636, 1982, 15 pp.

Minerals Information, Policy, and Analysis[1]

Ampian, S. G., and W. T. Adams. Guyana Refractory Bauxite: Stocks and Monthly Consumption as of August 31, 1979. Impact of the GRB Shortage on the Refractory Industry and General Background Material. Pres. at 109th Ann. AIME Meeting, Las Vegas, Nev., Feb. 24-29, 1980, AIME Preprint 80-115, 13 pp.

Armstrong, M. K., and P. C. Mory. Mineral Resources of Big Sandy and West Elliotts Creek RARE II Further Planning Areas and Reed Brake RARE II Wilderness Area, Tuscaloosa, Hale, and Bibb Counties, Alabama. BuMines MLA 50-82, 1982, 23 pp.; Eastern Field Operations Center.

Armstrong, M. K., and M. L. Dunn, Jr. Mineral Resources of Upper Buffalo Wilderness Area and Buffalo Addition RARE II Wilderness Area; Newton County, Arkansas. BuMines MLA 40-82, 1982, 19 pp.; Eastern Field Operations Center.

Avery, D. W. Mineral Resources of the Tepusquet Peak RARE II Area (No. 5-116), Santa Maria County, California. BuMines MLA 7-81, 1981, 6 pp.; Western Field Operations Center.

Balazik, R. F. The Impact of U.S. Railroad Abandonment on Domestic Mineral Industries. BuMines IC 8834, 1980, 18 pp.

Barker, J. C. Coal and Uranium Investigation of the Yukon Flats Cenozoic Basin. BuMines OFR 140-81, September 1981, 63 pp.

———. Mineral Investigations of Certain Lands in the Eastern Brooks Range, Alaska, 1978. BuMines OFR 37-81, 1981, 288 pp.

———. Mineral Investigations in the Porcupine River Drainage, Alaska. BuMines OFR 27-81, March 1981, 201 pp.

———. Occurrences and Potential for Lead and Zinc Mineralization in the Mt. Schwatka Region. BuMines OFR 70-80, 1980, 51 pp.

———. Reconnaissance of Rare-Metal Occurrences Associated With the Old Crow Batholith, Eastern Alaska-Northwestern Canada. Short Notes on Alaskan Geology, 1981. Alaska State Dept. of Nat. Res., College, Alaska, Geol. Rept. 73, 1982, pp. 43-49.

Barker, J. C., J. C. Still, T. C. Mowatt, and J. J. Mulligan. Critical and Strategic Minerals in Alaska: Cobalt, the Platinum-Group Metals, and Chromite. BuMines IC 8869, 1981, 8 pp.

Barnes, D. J. Mineral Resources of the La Panza RARE II Area (No. 5109), San Luis Obispo County, California. BuMines MLA 34-81, 1981, 10 pp.; Western Field Operations Center.

Benham, J. R. Mineral Resources of the Blue Joint Mtn. RARE II Area (No. 1-941), Ravalli County, Montana. BuMines MLA 21-81, 1981, 8 pp.; Western Field Operations Center.

———. Mineral Resources of the Long Swamp RARE II Area (No. A6024), Okanogan County, Washington. BuMines MLA 12-82, 1981, 6 pp.; Western Field Operations Center.

———. Mineral Resources of the Windigo Theilson RARE II Area, No. 6132, Douglas and Klamath Counties, Oregon. BuMines MLA 11-81, 1981, 6 pp.; Western Field Operations Center.

———. Summary Report on Mineral Resources of the West Pioneer RARE II Area, No. 1-006, Beaverhead County, Montana. BuMines MLA 4-81, 1981, 12 pp.; Western Field Operations Center.

Benham, J. R., and R. B. McCulloch. Mineral Resources of the La Brea RARE II Area (No. 5117), Santa Barbara County, California. BuMines MLA 9-82, 1981, 9 pp.; Western Field Operations Center.

Beresford, S. M., and H. G. Edler. Evaluation of Selected Factors Impacting on the International Competitiveness of the U.S. Minerals Industry. BuMines OFR 85-80, Nov. 13, 1978, 255 pp.

Berg, A. W., and F. V. Carillo. MILS: The Mineral Industry Location System of the Federal Bureau of Mines. BuMines IC 8815, 1980, 24 pp.

Bitar, R. F., and M. K. Armstrong. Mineral Resources of Bread Loaf RARE II Further Planning Area, Addison and Washington Counties, Vermont. BuMines MLA 65-82, 1982, 15 pp.; Eastern Field Operations Center.

Bitar, R. F., and T. M. Crandall. Mineral Resources of Sandy Creek RARE II Further Planning Area, Adams County, Mississippi. BuMines MLA 48-82, 1982, 18 pp.; Eastern Field Operations Center.

Butterman, W. C. Production and Uses of Zinc. Ch. in Zinc in the Environment, John Wiley & Sons, Inc., New York, pt. 1, 1980, pp. 1-38.

Capstick, D. O. Mineral Investigation of the San Joaquin RARE II Area (No. F5407), Madera County, California. BuMines MLA 79-82, 1982, 9 pp.; Western Field Operations Center.

Capstick, D. O., and P. C. Hyndman. Mineral Resources of the Diablo RARE II Area (No. 5127), Santa Barbara County, California. BuMines MLA 55-82, 1982, 7 pp.; Western Field Operations Center.

[1] Reports designated MLA (Mineral Land Assessment) are available for consultation at the offices of Field Assessment and Evaluation Staff, Washington, D.C., the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C., and the field offices indicated.

_____. Mineral Resources of the Little Pine RARE II Area (No. 5278), Santa Barbara County, California. BuMines MLA 53-82, 1982, 7 pp.; Western Field Operations Center.

Capstick, D. O., and A. L. Stump. Mineral Investigation of the Table Mountain RARE II Area (No. 5035), Inyo County, California. BuMines MLA 80-82, 1982, 10 pp.; Western Field Operations Center.

Carnes, D. Alaska's Minerals: A Look at 1979. Alaska Construct. & Oil., January 1980, pp. 40-43.

Cammarota, V. A., Jr. Production and Uses of Zinc. Ch. in Zinc in the Environment. John Wiley & Sons, Inc., New York, pt. 1, 1980, pp. 1-38.

Cammarota, V. A., Jr., W. J. Mo, and B. W. Klein. Projections and Forecasts of U.S. Mineral Demand by the U.S. Bureau of Mines. Proc. 109th AIME Ann. Meeting, Las Vegas, Nev., Feb. 24-29, 1980, pp. 69-71.

Canterbery, E. R., C. W. Hale, and E. J. Nosari. Economic Impact of the Phosphate Rock Industry on Selected Florida Counties, Florida, and the United States. BuMines OFR 21-80, September 1978, 101 pp.

Cather, E. E., and J. L. Ritchey. Mineral Resources of the Fisher Gulch RARE II Area (No. A5299), Trinity County, California. BuMines MLA 25-81, 1981, 10 pp.; Western Field Operations Center.

_____. Mineral Resources of the Lake Eleanor RARE II Area (No. 5807), Trinity County, California. BuMines MLA 15-82, 1981, 10 pp.; Western Field Operations Center.

Cather, E. E., and D. F. Scott. Mineral Resources of the Rubicon RARE II Area (No. 5026), El Dorado and Placer Counties, California. BuMines MLA 54-82, 1982, 9 pp.; Western Field Operations Center.

Causey, J. D. Mineral Resources of the Mount Hood Wilderness, Clackamas and Hood River Counties, Oregon. BuMines MLA 37-82, 1982, 13 pp.; Western Field Operations Center.

_____. Mineral Resources of the Mount Washington Wilderness, Deschutes, Lane, and Linn Counties, Oregon. BuMines MLA 38-82, 1982, 6 pp.; Western Field Operations Center.

Causey, J. D., and S. L. Willett. Mineral Resources of the Three Sisters Wilderness, Deschutes, Lane, and Linn Counties, Oregon. BuMines MLA 22-82, 1981, 12 pp.; Western Field Operations Center.

Chatman, M. L. Mineral Investigations of Unaka Mountain RARE II Further Planning Area, Unioci County, Tennessee. BuMines MLA 87-82, 1982, 16 pp.; Eastern Field Operations Center.

_____. Mineral Resources of the Snowbird RARE II Further Planning Area; Graham County, North Carolina. BuMines MLA 48-82, 1982, 18 pp.; Eastern Field Operations Center.

Chin, E. China. Sec. in Mining Annual Review 1982, Min. J. Ltd., London, 1982, pp. 385-391.

Clautice, K. H., and T. C. Mowatt. Trona Occurrences Within the Yukon Flats Basin, Alaska. BuMines OFR 69-81, 1981, 34 pp.

Clement, G. K., Jr., R. L. Miller, P. A. Seibert, L. Avery, and H. Bennett. Capital and Operating Cost Estimating System Manual for Mining and Beneficiation of Metallic and Nonmetallic Minerals Except Fossil Fuels in the United States and Canada. BuMines Spec. Rept. 4-81, 1981, 149 pp.

Close, T. J. Mineral Resources of the Welcome Creek Wilderness, Granite County, Montana. BuMines MLA 17-82, 1981, 15 pp.; Western Field Operations Center.

Close, T. J., J. D. Causey, S. L. Willett, and C. M. Rumsey. Mineral Resources of the Hyalite-Porcupine-Buffalo Horn Wilderness Study Area (RARE II Areas No. 1-158 G, Gallatin Divide; and H, Hyalite), Gallatin and Park Counties, Montana. BuMines MLA 6-81, 1981, 11 pp.; Western Field Operations Center.

Close, T. J., F. E. Federspiel, J. D. Causey, S. L. Willett, R. W. Morris, and J. R. Huffsmith. Mineral Resources of the Anaconda Pintlar Wilderness, Beaverhead, Deer Lodge, Granite and Ravalli Counties, Montana. BuMines MLA 24-82, 1982, 23 pp.; Western Field Operations Center.

Close, T. J., F. E. Federspiel, and A. Leszcykowski. Mineral Resources of the Hells Canyon Study Area, Adams, Idaho, and Nez Perce Counties, Idaho, and Wallowa County, Oregon. BuMines MLA 41-82, 1982, 32 pp.; Western Field Operations Center.

Colp, D. B. Fortymile Placer District Resource Inventory, Alaska. BuMines OFR 43-80, 1980, 16 pp.

Conyac, M. D. Mineral Resources of the Mt. Henry RARE II Area (No. 1-666), Lincoln County, Montana. BuMines MLA 2-82, 1981, 7 pp.; Western Field Operations Center.

_____. Summary of Mineral Resources of the Lake Fork RARE II Area (Study Area 6290) Baker and Wallowa Counties, Oregon. BuMines MLA 1-81, 1981, 9 pp.; Western Field Operations Center.

Cooper, F. D. Auxiliary Fuels in U.S. Blast Furnaces: 1979 and 1980. Iron and Steel Eng., v. 59, No. 7, July 1982, pp. 62-63.

_____. Coal Liquefaction. Encyclopedia of Energy, McGraw-Hill Book Co., Inc., New York, 2d ed., 1980, pp. 136-139.

_____. Potential "Met" Coke Production Capacity: The Case is Anything but Closed. 33 Metal Producing, v. 19, No. 9, September 1981, pp. 65-67.

_____. Potential Production Capacity of Metallurgical Coke. Iron and Steel Eng., v. 58, No. 9, September 1981, pp. 52-57.

Crandall, T. M. Mineral Investigations of the Savannah RARE II Further Planning Area, Liberty County, Florida. BuMines MLA 86-82, 1982, 22 pp.; Eastern Field Operations Center.

_____. Mineral Resources of Farles Prairie and Buck Lake RARE II Further Planning Areas; Marion County, Florida. BuMines MLA 46-82, 1982, 20 pp.; Eastern Field Operations Center.

_____. Mineral Resources of the Natural RARE II Further Planning Area; Baker County, Florida. BuMines MLA 30-81, 1981, 22 pp.; Eastern Field Operations Center.

Cwick, G. J., E. L. McHugh, J. D. Causey, and R. S. Gaps. Mineral Resources of the Rice Valley Wilderness Study Area, Riverside County, California. BuMines MLA 59-82, 1982, 10 pp.; Western Field Operations Center.

Davidoff, R. L. Supply Analysis Model (SAM): A Minerals Availability System Methodology. BuMines IC 8820, 1980, 45 pp.

Davis, M. P. Mineral Resources of Overflow Further Planning Area, Rabun County, Georgia, and Macon County, North Carolina. BuMines MLA 31-32, 1982, 16 pp.; Eastern Field Operations Center.

Davis, H. C., and E. M. Lofting. Development of Interindustry Transactions Data on the Structure of United States Mining Industries for 1967 and a Comparison of Techniques for Updating Related Input-Output Coefficients. BuMines OFR 19-80, Apr. 30, 1979, 49 pp.; NTIS, PB 80-161425.

_____. The Input-Output Structure of the U.S. Mineral Industries for 1958 and 1963: Transactions, Employment, and Multipliers. BuMines OFR 20-80, April 1979, 60 pp.; NTIS, PB 80-160286.

Denton, D. K., Jr. Mineral Investigation of the Pine Creek RARE II Area (No. 6248), Harney County, Oregon. BuMines MLA 101-82, 1982, 7 pp.; Western Field Operations Center.

———. Mineral Resource Potential of the Upper Priest Lake RARE II Area (A1-123), Bonner County, Idaho. BuMines MLA 2-81, 1981, 9 pp.; Western Field Operations Center.

———. Mineral Resources of the Los Machos Hills RARE II Area (No. 5111), San Luis Obispo County, California. BuMines MLA 3-82, 1981, 8 pp.; Western Field Operations Center.

Dunn, M. L. Mineral Resources of the Shining Rock Wilderness; Haywood County, North Carolina. BuMines MLA 13-81, 17 pp.; Eastern Field Operations Center.

Dunn, M. L., Jr., G. C. Gazdik, and J. J. Hill. Mineral Resources Investigation of Rainbow Lake Wilderness Area and Flynn Lake Wilderness Study Area, Bayfield County, Wisconsin. BuMines MLA 32-82, 1982, 29 pp.; Eastern Field Operations Center.

Dunn, M. L., Jr., and D. K. Harrison. Mineral Resources of the Caney Creek Wilderness Area, Polk County, Arkansas. BuMines MLA 12-81, 1981, 33 pp.; Eastern Field Operations Center.

Ellis, C. E. Mineral-Resource Potential of the Mazatzal Wilderness and Contiguous RARE II Further Planning Area, Gila, Maricopa, and Yavapai Counties, Arizona. BuMines MLA 56-82, 1982, 12 pp.; Intermountain Field Operations Center.

Ellis, C. E., and D. G. Scott. Mineral Resources Investigation of the Ryan Hill RARE II Further Planning Area, Socorro County, New Mexico. BuMines MLA 78-82, 1982, 8 pp.; Intermountain Field Operations Center.

Esparza, L. E., and C. Sabine. Mineral Resources of the Additions to the Ventana Wilderness, Monterey County, California. BuMines MLA 25-82, 1982, 9 pp.; Western Field Operations Center.

Fechner, S. A., and M. P. Meyer. Bureau of Mines Studies Forest Appraisal Part of RARE II Program. Alaska Miner, v. 10, No. 5, May 1982, pp. 13, 18.

———. Placer Sampling and Related Bureau of Mines Activities in the Sound Study Area of the Chugach National Forest, Alaska. BuMines MLA 62-82, 1982, 25 pp.; Alaska Field Operations Center.

Federspiel, F. E., H. W. Campbell, D. F. Scott, and J. M. Spear. Mineral Resources of the Dinkey Lakes RARE II Area (No. 4244), Fresno County, California. BuMines MLA 24-81, 1981, 14 pp.; Western Field Operations Center.

Federspiel, F. E., E. E. Cather, and D. F. Scott. Mineral Resources of the Granite Chief RARE II Area (A5-2611), Placer County, California. BuMines MLA 14-81, 1981, 13 pp.; Western Field Operations Center.

Federspiel, F. E., and J. D. Huffsmith. Mineral Resources of the Big Snowies Wilderness Study Area (RARE II 1-739) Fergus and Golden Valley Counties, Montana. BuMines MLA 18-82, 1981, 8 pp.; Western Field Operations Center.

Federspiel, F. E., A. M. Leszcykowski, and F. A. Spicker. Mineral Resources of the North Fork American River (5-262) RARE II Study Area, Placer County, California. BuMines MLA 20-82, 1981, 17 pp.; Western Field Operations Center.

Federspiel, F. E., D. F. Scott, and E. E. Cather. Mineral Resources of the Raymond Peak RARE II Area (No. 4985), Alpine County, California. BuMines MLA 4-82, 1981, 18 pp.; Western Field Operations Center.

Federspiel, F. E., D. F. Scott, E. E. Cather, N. T. Zilka, and A. M. Leszcykowski. Mineral Resources of the Log Cabin Saddlebag (5052), Hall Natural Area (5051), Horse Meadow (5049), Tioga Lake (5050), RARE II Study Areas, Mono County, California. BuMines MLA 7-82, 1981, 16 pp.; Western Field Operations Center.

Foley, J. Y. Alkaline Igneous Rocks in the Eastern Alaska Range. Short Notes on Alaskan Geology, 1981. Alaska State Dept. Nat. Res., College, Alaska, Geol. Rept. 73, 1982, pp. 1-5.

Foley, J., and J. C. Barker. Tungsten Investigations Near VABM Bend, Eastern Alaska. BuMines OFR 29-81, March 1981, 24 pp.

Gabby, P. N. Mineral Investigation of the Arroyo Seco RARE II Area (No. 5012), Los Angeles County, California. BuMines MLA 104-82, 1982, 9 pp.; Western Field Operations Center.

———. Mineral Resources of the Black Mountain RARE II Area (No. 5108), San Luis Obispo County, California. BuMines MLA 21-82, 1981, 12 pp.; Western Field Operations Center.

Gazdik, G. C. Mineral Resource Investigation of Carr Mountain RARE II Further Planning Area, Grafton County, New Hampshire. BuMines MLA 70-82, 1982, 18 pp.; Eastern Field Operations Center.

———Mineral Resources of Ellicott Rock Wilderness Area and Additions; Oconee County, South Carolina, Macon and Jackson Counties, North Carolina, and Rabun County, Georgia. BuMines MLA 29-81, 1981, 45 pp.; Eastern Field Operations Center.

———. Mineral Resources of the Little Frog Mountain RARE II Area, Polk County, Tennessee. BuMines MLA 23-81, 1981, 15 pp.; Eastern Field Operations Center.

Gazdik, G. C., and P. T. Behum. Mineral Resources of the Gee Creek Wilderness Area, Polk and Montroe Counties, Tennessee. BuMines MLA 15-81, 1981, 31 pp.; Eastern Field Operations Center.

Gazdik, G. C., and M. L. Dunn, Jr. Mineral Resources of Cohutta Wilderness Area, Big Frog Wilderness Study Area, and Hemp Top and Big Frog Additions RARE II Areas, North-Central Georgia and Southwestern Tennessee. BuMines MLA 47-82, 1982, 31 pp.; Eastern Field Operations Center.

Gazdik, G. C., and D. K. Harrison. Mineral Resources of the Linville Gorge Wilderness and Additions, Burke and McDowell Counties, North Carolina. BuMines MLA 16-81, 1981, 34 pp.; Eastern Field Operations Center.

Girol, V. P. Mineral Resource Investigation of Allegheny Front and Hickory Creek RARE II Further Planning Areas; Warren County, Pennsylvania. BuMines MLA 28-82, 1982, 26 pp.; Eastern Field Operations Center.

Grichar, J. S., R. Levine, and L. Nahai. The Nonfuel Mineral Outlook for the U.S.S.R. Through 1990. BuMines Mineral Issues, 1981, 17 pp.

Hall, W. B. Bureau of Mines Forecasts of Supply and Demand for Major Industrial Minerals. Trans. 4th Industrial Minerals Internat. Cong., Atlanta, Ga., 1980. Metal Bulletin Congresses, Ltd., New York, 1980, pp. 211-219.

Hamilton, M. M., and R. T. Mayerle. Mineral Investigations of the Middle Fork Judith RARE II Area (No. 1734), and the Included Middle Fork Judith Wilderness Study Area, Judith Basin and Meagher Counties, Montana. BuMines MLA 92-82, 1982, 18 pp.; Western Field Operations Center.

Hammack, R. W., and V. P. Girol. Mineral Resources of Kinsman Mountain RARE II Further Planning Area, Grafton County, New Hampshire. BuMines MLA 58-82, 1982, 15 pp.; Eastern Field Operations Center.

Hammack, R. W., and R. B. Ross, Jr. Mineral Resources of Beaver Creek Wilderness; McCreary County, Kentucky. BuMines MLA 26-82, 1982, 40 pp.; Eastern Field Operations Center.

Hanson, E., G. Sherman, and J. Knaebel. Preliminary Report on the Mineral Potential of the Alaska Peninsula. BuMines OFR 36-81, 1981, 39 pp.

Harris, L. E. Mineral Resources of Belle Starr East RARE II Further Planning Area and Belle Starr West RARE II Further Planning Area; Scott and Sebastian Counties, Arkansas. BuMines MLA 27-81, 1981, 25 pp.; Eastern Field Operations Center.

Harrison, D. K. Mineral Resources of the Lye Brook Wilderness, Bennington, and Windham Counties, Vermont. BuMines MLA 17-81, 1981, 21 pp.; Eastern Field Operations Center.

Harrison, D. K., and M. K. Armstrong. Mineral Resources of Shinbone Creek and Adams Gap RARE II Further Planning Area; Clay County, Alabama. BuMines MLA 43-82, 1982, 19 pp.; Eastern Field Operations Center.

Hoekzema, R. B. Placer Sampling and Related Bureau of Mines Activities on the Kenai Peninsula, Alaska. BuMines OFR 138-81, September 1981, 28 pp.

Hoekzema, R. B., and G. E. Sherman. Billings Glacier Molybdenum-Copper Occurrence, Whittier, Alaska. BuMines OFR 141-81, 1981, 30 pp.

Iverson, S. R. Mineral Resources of the Buttermilk RARE II Area (No. 5-038), Inyo County, California. BuMines MLA 22-81, 1981, 7 pp.; Western Field Operations Center.

Iverson, S. R. Mineral Investigation of the Wonder Mountain RARE II Area (No. 6086), Mason County, Washington. BuMines MLA 105-82, 1982, 11 pp.; Western Field Operations Center.

Jansons, U. 1979 Bureau of Mines Sampling Sites and Analytical Results for Samples Collected in the Chugach National Forest, Alaska. BuMines OFR 83-81, 1981, 229 pp.

———. Preliminary Evaluation of Geochemical Data From the Proposed Chukchi Imuruk National Reserve, Alaska. BuMines OFR 28-81, March 1981, 8 pp.

Jansons, U., and D. W. Baggs. Mineral Investigations of the Misheguk Mountain and Howard Pass Quadrangles, National Petroleum Reserve-Alaska. BuMines OFR 38-80, 1980, 76 pp.

Jansons, U., and M. A. Parke. 1978 Mineral Investigations in the Misheguk Mountain and Howard Pass Quadrangles, Alaska. BuMines OFR 26-81, 1980, 295 pp.

Johnson, W., and J. Paone. Land Utilization and Reclamation in the Mining Industry, 1930-80. BuMines IC 8862, 1982, 22 pp.

Johnson, F. L., H. K. Thurber, R. W. Morris, T. J. Peters, and D. S. Lindsey. Mineral Resources of the John Muir Wilderness; Fresno, Inyo, Madera, and Mono Counties, California. BuMines MLA 2-81, 1981, 18 pp.; Western Field Operations Center.

Jolly, J. L. W., and C. T. Collins. Iron Oxide Pigments (in Two Parts) 2. Natural Iron Oxide Pigments—Location, Production, and Geological Description. BuMines IC 8813, 1980, 79 pp.

Jones, J. G., M. E. Piros, and R. W. Hammack. Mineral Resources of Dolly Anne RARE II Further Planning Area, Alleghany County, Virginia. BuMines MLA 61-82, 1982, 37 pp.; Eastern Field Operations Center.

Kilgore, C. C., and P. R. Thomas. Manganese Availability—Domestic. A Minerals Availability System Appraisal. BuMines IC 8889, 1982, 14 pp.

Klinger, F. L. Iron Ore. Sec. in Mining Annual Review 1981, Min. J. Ltd., London, 1981, pp. 69-72.

———. Iron Ore. Sec. in Mining Annual Review 1982, Min. J. Ltd., London, 1982, pp. 61-65.

Kostick, D. S., and R. J. Foster. Soda Ash (Sodium Carbonate), Sodium Sulfate, and Sodium. BuMines MCP, 1980, 14 pp.

Kreidler, T. J. Mineral Resource Potential of the Dragon Mountains RARE II Further Planning Area, Cochise County, Arizona. BuMines MLA 35-82, 1982, 9 pp.; Intermountain Field Operations Center.

Kuizon, L. Mineral Investigation of the Antimony RARE II Area (No. 5136), Kern County, California. BuMines MLA 71-82, 1982, 14 pp.; Western Field Operations Center.

———. Mineral Resources of the Cuyama RARE II Study Area 5-135, Santa Barbara and Ventura Counties, California. BuMines MLA 9-81, 1981, 11 pp.; Western Field Operations Center.

Lambeth, R. H. Mineral Resources of the Matilija RARE II Area (No. 5129), Ventura and Santa Barbara Counties, California. BuMines MLA 64-82, 1982, 13 pp.; Western Field Operations Center.

Lambeth, R. H., S. W. Schmauch, R. T. Mayerle, and M. M. Hamilton. Mineral Investigations of the Madison RARE II Areas (No. 1549, Parts E, J, N, R, and S), Madison and Gallatin Counties, Montana. BuMines MLA 81-82, 1982, 31 pp; Western Field Operations Center.

Lane, M. E. Mineral-Resource Potential of the Lower San Francisco RARE II Further Planning and Wilderness Recommendation Areas, Greenlee County, Arizona, Grant and Catron Counties, New Mexico. BuMines MLA 13-82, 1981, 7 pp.; Intermountain Field Operations Center.

———. Mineral-Resource Potential of the Paria Plateau Wilderness Study Area, Coconino County, Arizona. BuMines MLA 63-82, 1982, 8 pp.; Intermountain Field Operations Center.

———. Mineral Resources of the Emmet Wash Wilderness Study Area, Coconino County, Arizona. BuMines MLA 30-82, 1982, 5 pp.; Intermountain Field Operations Center.

Langton, T. G., and P. N. Yasnowsky. Mineral Industries. The Encyclopedia of Mineralogy, Encyclopedia of Earth Sciences, ed. by K. Frye. Hutchinson Ross Publishing Co., Stroudsburg, Pa., v. 4B, 1981, pp. 258-270.

Larson, C. E. Mineral Resources of the Square Butte Instant Wilderness Study Area, Chouteau County, Montana. BuMines MLA 45-82, 1982, 7 pp.; Western Field Operations Center.

Lawrence, H., A. Prelat, and R. J. P. Lyon. Application of Landsat Imagery to Kaolin Mining Operations in the Southeastern United States. SME-AIME Annual, No. 270, June 1982, pp. 1841-1847.

Leszcykowski, A. M., and J. D. Causey. Mineral Investigation of the Coxcomb Mountains Wilderness Study Area (BLM), Riverside and San Bernardino Counties, California. BuMines MLA 94-82, 1982, 11 pp.; Western Field Operations Center.

Leszcykowski, A., C. Morlock, and S. Willett. Mineral Resources of the Domeland Wilderness, Kern and Tulare Counties, California. BuMines MLA 36-82, 1982, 5 pp.; Western Field Operations Center.

———. Mineral Resources of the Kaiser Wilderness Study Area, Fresno County, California. BuMines MLA 57-82, 1982, 9 pp.; Western Field Operations Center.

Levine, R. M. Soviet Union. Sec. in Mining Annual Review 1982, Min. J. Ltd., London, 1982, pp. 489-503.

Lipton, D. A. Mineral Investigation of the Pleasant View RARE II Area (No. 5008), Los Angeles County, California. BuMines MLA 66-82, 1982, 8 pp.; Western Field Operations Center.

———. Mineral Resources of the Garcia Mountain RARE II Area (No. 5107), San Luis Obispo County, California.

BuMines MLA 8-82, 1981, 9 pp.; Western Field Operations Center.

Lofting, E. M., H. C. Davis, and W. O. Schink. The Input-Output Structure of the U.S. Mineral Industries for 1967 With RAS Updates to 1972 and 1977. BuMines OFR 72-81, February 1980, 47 pp.; NTIS, PB 81-225898.

Longwill, W. D. Mineral Resources of the Big Butte-Shinbone (5145), East Fork (5226), Murphy Glade (5298), and Wilderness Contiguous (5137) RARE II Proposed Additions to the Yolla Bolly-Middle Eel Wilderness, Trinity, Tehama, and Mendocino Counties, California. BuMines MLA 3-81, 1981, 13 pp.; Western Field Operations Center.

———. Mineral Resources of the Kings River (B5-198) and Rancheria (C5-198) RARE II Areas, Fresno County, California. BuMines MLA 5-82, 1981, 25 pp.; Western Field Operations Center.

———. Mineral Resources of the Sawmill-Badlands RARE II Area (No. 5134), Ventura and Kern Counties, California. BuMines MLA 51-82, 1982, 18 pp.; Western Field Operations Center.

Lynd, L. E. Titanium Minerals. Min. Eng., v. 32, No. 5, May 1980, pp. 587-588.

Marcone, A. J., and V. A. Cammarota, Jr. An Overview of the International Lead and Zinc Study Group. Proc. Lead Industries Assoc., Inc., and Zinc Inst., Inc., Ann. Meeting, St. Louis, Mo., Mar. 8-10, 1982, pp. 173-180.

Marks, L. Y. Mineral Resources of the Reservoir-North RARE II Area (No. H1-485), Teton County, Montana. BuMines MLA 11-82, 1981, 6 pp.; Western Field Operations Center.

Marsden, R. W. Estimation and Evaluation of the Iron Ore Reserves of the United States—A Partial Survey 1974-75. Iron Ore Reserves of the Mesabi Range, Minnesota. A Minerals Availability System Report. BuMines OFR 109-80, Jan. 23, 1980, 81 pp.; NTIS, PB 80-228984.

Martin, C. M., and T. J. Wawro. Mineral Investigations of Mount Wolf-Gordon Pond RARE II Further Planning Area, Grafton County, New Hampshire. BuMines MLA 88-82, 16 pp.; Eastern Field Operations Center.

Martino, O., D. Hyde, and P. Velasco. Mineral Industries of Latin America. BuMines Mineral Perspective, 1981, 116 pp.

McColly, R. A., and S. L. Korzeb. Mineral Resource Potential of the Arnold Mesa RARE II Further Planning Area, Yavapai County, Arizona. BuMines MLA 31-81, 1981, 11 pp.; Intermountain Field Operations Center.

McDermott, M. M., J. Y. Foley, and D. D. Southworth. Investigation of a Copper Occurrence in the Rampart Diorites. BuMines OFR 143-81, 1981, 26 pp.

McHugh, E. L., and C. M. Rumsey. Mineral Investigation of the Caribou Wilderness, Lassen and Plumas Counties, California. BuMines MLA 100-82, 1982, 7 pp.; Western Field Operations Center.

Meisinger, A. C. Vermiculite in 1980. Min. Eng. v. 33, No. 5, May 1981, p. 592.

Miller, F. W. Mineral Investigations of Dartmouth Range RARE II Further Planning Area, Coos County, New Hampshire. BuMines MLA 90-82, 1982, 18 pp.; Eastern Field Operations Center.

Miller, M. Mineral Resources of the Carson-Iceberg Area (RARE II C-4-986, C-5-986, B-5-986 North, and B-5-986 South), Alpine and Tuolumne Counties, California. BuMines MLA 8-81, 1981, 16 pp.; Western Field Operations Center.

Minerals Data Working Group, Interagency Minerals Information Coordinating Committee. Minerals Data Source Directory. BuMines IC 8881, 1982, 296 pp.

Mo, W. Y., and B. W. Klein. Bureau of Mines Statistical Projection Methodology of U.S. Mineral Consumption by End Use: Aluminum as an Example. BuMines IC 8825, 1980, 109 pp.

Mory, P. C. Mineral Resources of the Bristol Cliffs Wilderness Areas, Addison County, Vermont. BuMines MLA 18-81, 1981, 15 pp.; Eastern Field Operations Center.

Mory, P. C., R. B. Ross, Jr., and P. T. Behum. Mineral Resources of the Sipsey Wilderness and RARE II Areas, Lawrence and Winston Counties, Alabama. BuMines MLA 19-81, 1981, 42 pp.; Eastern Field Operations Center.

Moyle, P. R., and C. M. Rumsey. Mineral Resources of the Diamond Peak Wilderness and Proposed Addition, Lane and Klamath Counties, Oregon. BuMines MLA 23-82, 1981, 10 pp.; Western Field Operations Center.

Nahai, L. Mineral Policies of Developed Consuming Countries. Proc. AIME Council of Economics Mineral Economics Symp., November 1979. Pub. as Materials and Society, Pergamon Press, Ltd., Elmsford, N.Y., v. 4, Nov. 1, 1980, pp. 11-13.

Nair, B. K., G. K. Schenck, and F. Demler. SIC Based End-Use Data Scheme for Information Critical Minerals. BuMines OFR 36-82, September 1978, 464 pp.; NTIS, PB 82-188707.

National Materials Advisory Board. Considerations in Choice of Form for Materials for the National Stockpile. National Academy Press, NMAB-378, March 1982, 206 pp.; NTIS, PB 82-202896.

Norman, L. D. Mineral Dependency Versus Mineral Vulnerability. Pres. at 83d Nat. Western Min. Conf., Denver, Colo., February 1980, 8 pp.

Opyrchal, A. M., and K. L. Wang. Economic Significance of the Florida Phosphate Industry. An Input-Output (I-O) Analysis. BuMines IC 8850, 1981, 62 pp.

Peters, T. J., and F. E. Federspiel. Mineral Resources of the Freel Peak RARE II Area (No. 5271), El Dorado County, California. BuMines MLA 44-82, 1982, 11 pp.; Western Field Operations Center.

Peters, T. J., and J. M. Linne. Mineral Resources and Potential of Goat Rocks RARE II Areas, No. 6036, Parts A, C, and D, Lewis and Yakima Counties, Washington. BuMines MLA 5-81, 1981, 9 pp.; Western Field Operations Center.

Peterson, G. R., D. I. Bleiwas, and P. R. Thomas. Cobalt Availability—Domestic. A Minerals Availability System Appraisal. BuMines IC 8848, 1981, 31 pp.

Peterson, G. R., R. L. Davidoff, D. I. Bleiwas, and R. J. Fantel. Alumina Availability—Domestic. A Minerals Availability System Appraisal. BuMines IC 8861, 1981, 23 pp.

Pittman, T. Mining Picks Up Across the State. Gold Was the Glamour Metal. Alaska Construction & Oil, v. 22, No. 6, June 1981, pp. 28, 30-31, 34.

Radcliffe, S. V., L. L. Fischman, and R. Schantz, Jr. Materials Requirements and Economic Growth: A Comparison of Consumption Patterns in Industrialized Countries. BuMines OFR 31-82, Dec. 18, 1981, 386 pp.; NTIS, PB 82-196270.

Rains, R. L., D. J. Barnes, H. W. Campbell, D. K. Denten, Jr., S. R. Iverson, R. E. Jeske, and S. A. Stebbins. Mineral Investigation of the Benton Range RARE II Area (No. 5056), Mono County, California. BuMines MLA 83-82, 1982, 15 pp.; Western Field Operations Center.

Ridenour, J. Mineral Resources of the Geahart Mountain Wilderness and RARE II Area 6225, Klamath and Lake Counties, Oregon. BuMines MLA 33-82, 1982, 6 pp.; Western Field Operations Center.

Ridenour, J., P. R. Moyle, and S. L. Willett. Mineral Resources of the Whipple Mountains Wilderness Study Area,

San Bernadino County, California. BuMines MLA 29-82, 1982, 34 pp.; Western Field Operations Center.

Ritchey, J. L., and E. E. Cather. Mineral Resources of the Trail Lake RARE II Area (No. B5-095), Lassen and Plumas Counties, California. BuMines MLA 10-82, 1981, 7 pp.; Western Field Operations Center.

Ross, R. B., Jr., and T. M. Crandall. Mineral Resources of the Lost Cove and Harper Creek RARE II Further Planning Areas; Avery and Caldwell Counties, North Carolina. BuMines MLA 1-82, 1981, 61 pp.; Eastern Field Operations Center.

Ross, R. B., Jr., and G. C. Gazdik. Mineral Resources of the James River Face Wilderness; Rockbridge and Bedford Counties, Virginia. BuMines MLA 28-81, 1981, 16 pp.; Eastern Field Operations Center.

Ross, R. B., Jr., and R. W. Hammack. Mineral Resources of Troublesome Further Planning Area; McCreary County, Kentucky. BuMines MLA 33-81, 1981, 21 pp.; Eastern Field Operations Center.

Ryan, G. S. Mineral Resources Investigation of the Chambers Ferry RARE II Further Planning Area, Sabine County, Texas. BuMines MLA 76-82, 1982, 5 pp.; Intermountain Field Operations Center.

———. Mineral Resources Investigation of the Four Notch RARE II Further Planning Area, Walker County, Texas. BuMines MLA 77-82 1982, 5 pp.; Intermountain Field Operations Center.

———. Mineral Resources Investigation of Graham Creek RARE II Further Planning Area, Angelina and Jasper Counties, Texas. BuMines MLA 74-82, 1982, 5 pp.; Intermountain Field Operations Center.

Sabin, A. E., and J. G. Jones. Mineral Resources of Devils Den RARE II Further Planning Area, Rutland and Windsor Counties, Vermont. BuMines MLA 34-82, 1982, 16 pp.; Eastern Field Operations Center.

Sabin, A. E., C. M. Martin, and R. M. Thompson. Mineral Investigation of Pemigewasset RARE II Further Planning Area, Grafton and Carroll Counties, New Hampshire. BuMines MLA 95-82, 1982, 16 pp.; Eastern Field Operations Center.

Sabine, C., and L. E. Esparza. Mineral Resources of the Santa Lucia Wilderness, San Luis Obispo County, California. BuMines MLA 16-82, 1981, 6 pp.; Western Field Operations Center.

Schenck, G. K., B. K. Nair, and K. L. Wang. SIC-Based Demand Information System for Nonfuel Minerals. BuMines IC 8877, 1982, 48 pp.

Schumacher, O. L., A. W. Berg, F. V. Carrillo, R. A. Pense, and R. B. Davis. Federal Land Status in the Overthrust Belt of Idaho, Montana, Utah, and Wyoming, 1979. BuMines Spec. Rept. 2-81, 1980, 22 pp.

Scott, D. F. Mineral Investigation of the Pyramid RARE II Area (No. 5023), El Dorado County, California. BuMines MLA 69-82, 1982, 7 pp.; Western Field Operations Center.

Scott, D. F., F. E. Federspiel, E. E. Cather, and H. W. Campbell. Mineral Investigation of the Dardanelles RARE II Areas (Nos. 4982 and 5982), Alpine and El Dorado Counties, California. BuMines MLA 82-82, 1982, 12 pp.; Western Field Operations Center.

Shekarchi, E., G. Morgan, P. Clarke, and S. Ambrosio. Zimbabwe. BuMines Mineral Perspective, 1981, 62 pp.

Sibley, S. F. Cobalt: A Strategic and Critical Resource for Industrialized Nations, Supplied by Developing Nations. Natural Resources Forum, United Nations, v. 4, No. 4, October 1980, pp. 403-413.

Singleton, R. H. Peat in the United States. Proc. 6th Internat. Peat Soc. Cong., Duluth, Minn., Aug. 17-23, 1980, pp. 96-102.

Sousa, L. J. The U.S. Copper Industry: Problems, Issues, and Outlook. BuMines Mineral Issues, 1981, 86 pp.

Spear, J. M. Mineral Resources of the Agnew RARE II Area (No. 5199), Fresno County, California. BuMines MLA 19-82, 1982, 9 pp.; Western Field Operations Center.

———. Mineral Resources of the Bear Mountain RARE II Area (No. 5103), Monterey County, California. BuMines MLA 60-82, 1982, 10 pp.; Western Field Operations Center.

———. Mineral Resources of the Oat Mountain RARE II Area (No. 5197), Fresno County, California. BuMines MLA 14-82, 1981, 9 pp.; Western Field Operations Center.

Spear, J. M., and R. McCulloch. Mineral Resources of the Domeland Addition (5207) and Woodpecker (5206) RARE II Areas, Tulare and Kern Counties, California. BuMines MLA 10-81, 1981, 11 pp.; Western Field Operations Center.

Spinrad, W. I., Jr. Iron Oxide Pigments. Min. Eng., v. 34, No. 5, May 1982, pp. 563-564.

Stebbins, S. A. Mineral Investigation of the Lincoln Creek RARE II Area (No. 5983), Douglas County, Nevada. BuMines MLA 93-82, 9 pp.; Western Field Operations Center.

———. Mineral Resources of the Black Butte RARE II Area (No. 5102), Monterey County, California. BuMines MLA 26-81, 1981, 9 pp.; Western Field Operations Center.

Still, J. C., and K. R. Weir. Mineral Land Assessment of the West Portion of the Western Chicagof Island, Southeast Alaska. BuMines OFR 89-81, 1981, 168 pp.

Stone, J. P., and L. M. Kaas. The Bureau of Mines Automated Minerals Information System—AMIS. Proc. 17th Internat. Symp. on Computer Applications in the Mineral Industry, Golden, Colo., Apr. 19-23, 1982; Ch. 67 in Application of Computers and Operations Research in the Mineral Industry, pp. 740-753.

Stotelmeyer, R. B., F. L. Johnson, E. L. Federspiel, D. K. Denten, Jr., and S. A. Stebbins. Mineral Investigation of the Glacier Peak Wilderness and Adjacent Areas, Chelan, Skagit, and Snohomish Counties, Washington. BuMines MLA 89-82, 1982, 36 pp.; Western Field Operations Center.

Sullivan, D. E. Minerals and the Tokyo Round of the MTN. BuMines IC 8854, 1981, 18 pp.

Thomas, P. R., R. L. Davidoff, and M. M. Quinn. The Depletion Allowance and Domestic Minerals Availability. A Case Study in Copper. BuMines IC 8874, 1982, 15 pp.

Thompson, R. M. Mineral Resource Investigation. Burden Falls RARE II Further Planning Area; Pope County, Illinois. BuMines MLA 32-81, 1981, 13 pp.; Eastern Field Operations Center.

———. Mineral Resource Investigation Lusk Creek RARE II Further Planning Area; Pope County, Illinois. BuMines MLA 6-82, 1981, 28 pp.; Eastern Field Operations Center.

Tilton, J. E., and W. A. Vogely. Market Instability in the Metal Industries. BuMines OFR 97-81, September 1980, 191 pp.

Tomimatsu, T. T. The U.S. Copper Mining Industry. A Perspective on Financial Health. BuMines IC 8836, 1980, 20 pp.

U.S. Bureau of Mines. Staff. Mineral Commodity Summaries, 1981. BuMines Spec. Pub., January 1981, 189 pp.

———. Mineral Commodity Summaries, 1982. BuMines Spec. Pub. 1-82, 1982, 183 pp.

———. Mineral Facts and Problems. BuMines Bull. 671, 1981, 80 ch., 1060 pp.

———. Minerals Yearbook, 1976. Volume III. Area Reports: International. 1980, 86 ch., 1392 pp.

———. Minerals Yearbook, 1977. Volume III. Area Reports: International. 1981, 93 ch., 1243 pp.

———. Minerals Yearbook, 1978-79. Volume I. Metals and Minerals. 1980, 73 ch., 1063 pp.

———. Minerals Yearbook, 1978-79. Volume II. Area Reports: Domestic. 1981, 53 ch., 596 pp.

———. Minerals Yearbook, 1978-79. Volume III. Area Reports: International. 1981, 93 ch., 1250 pp.

———. Minerals Yearbook, 1980. Volume I. Metals and Minerals. 1981, 72 ch., 950 pp.

———. Minerals Yearbook, 1980. Volume II. Area Reports: Domestic. 1982, 52 ch., 603 pp.

———. Minerals Yearbook, 1980. Volume III. Area Reports: International. 1982, 92 ch., 1367 pp.

U.S. Bureau of Mines, Staff—Alaska Field Operations Center. Mineral Appraisal of the Proposed Utukok and Colville Wild and Scenic Rivers: A Summary Report. BuMines OFR 37-80, Apr. 2, 1980, 8 pp.

———. Mineral Deposits of the Cape Krusenstern Area, Alaska: A Preliminary Comment. BuMines OFR 42-80, 1980, 19 pp.

Wawro, T. J., M. L. Chatman, and P. T. Behum. Mineral Investigation of the Southern Massanutten RARE II Further Planning Area, Page and Rockingham Counties, Virginia. BuMines MLA 73-82, 1982, 26 pp.; Eastern Field Operations Center.

Weisner, R. C., J. F. Lemons, Jr., and L. V. Coppa. Valuation of Potash Occurrences Within the Nuclear Waste Isolation Pilot Plant Site in Southeastern New Mexico. BuMines IC 8814, 1980, 94 pp.

Welsh, R. A., Jr., and P. T. Behum. Mineral Investigation of the Clarion River RARE II Further Planning Area, Elk County, Pennsylvania. BuMines MLA 85-82, 1982, 32 pp.; Eastern Field Operations Center.

Welsh, R. A., Jr., and R. H. Grau III. Mineral Resource Investigation of Cornplaster RARE II Further Planning Area; Warren County, Pennsylvania. BuMines MLA 39-82, 1982, 24 pp.; Eastern Field Operations Center.

Welsh, R. A., Jr., and L. E. Harris. Mineral Resources of Jobildunk RARE II Further Planning Area; Grafton County, New Hampshire. BuMines MLA 27-82, 1982, 17 pp.; Eastern Field Operations Center.

White, W. W., III. Mineral Investigation of the Dry Lakes RARE II Area (No. 5131), Ventura County, California. BuMines MLA 84-82, 1982, 17 pp.; Western Field Operations Center.

———. Mineral Investigation of the Quatal RARE II Area (No. 5268), Ventura County, California. BuMines MLA 68-82, 1982, 15 pp.; Western Field Operations Center.

Witzig, T. J. Operation of the International Tin Agreement. BuMines IC 8860, 1981, 24 pp.

Wolfe, T. W., B. P. Malashevich, C. Chandler, C. Morgan, B. Rubenking, and V. Honnold. The Price-Responsiveness of Secondary Silver. BuMines OFR 74-82, March 1982, 146 pp.; NTIS, PB 82-208422.

Wood, R. H., II. Mineral Resources Investigation of the Richland Creek Addition RARE II Further Planning Area, Newton and Searcy Counties, Arkansas. BuMines MLA 96-82, 1982, 7 pp.; Intermountain Field Operations Center.

Yasnowsky, P. N., and A. P. Graham. Mineral Depletion Allowances and U.S. Import Dependence. BuMines IC 8824, 1980, 13 pp.

——— State Severance Taxes: A Summary and an Analysis of the Impact of Rate Changes on Copper Recovery Costs. BuMines IC 8879, 1982, 23 pp.

Zilka, N. T. Mineral Resources of the Golden Trout Wilderness, Tulare and Inyo Counties, California. BuMines MLA 52-82, 1982, 9 pp.; Western Field Operations Center.

Zilka, N. T., and A. M. Leszcykowski. Mineral Resources of the Hoover Wilderness and Proposed RARE II Additions 4-662, 5-662, 4-664, 4-666, Mono and Toulumne Counties, California. BuMines MLA 49-82, 1982, 13 pp.; Western Field Operations Center.

Zlobik, A. B. Mica in 1980. Min. Eng., v. 33, No. 5, May 1981, pp. 580-582.

Helium

Holland, P. W. A Method for Determining Helium in Water. BuMines RI 8578, 1981, 17 pp.

Loya, E. W., C. A. Seitz, and D. E. Emerson. Gravimetric Preparation of Primary Standard Gas Mixtures in the Parts Per Trillion Range. BuMines RI 8643, 1982, 4 pp.

Lucich, G. M., and P. W. Holland. A Proportional Temperature Controller With Automatic Shutoff. BuMines RI 8423, 1980, 8 pp.

Moore, B. J. Analyses of Natural Gases, 1917-80. BuMines IC 8870, 1982, 1055 pp.

———. Analyses of Natural Gases, 1979. BuMines IC 8833, 1980, 100 pp.

———. Analyses of Natural Gases, 1980. BuMines IC 8856, 1981, 236 pp.

———. Helium Resources of the United States, 1979. BuMines IC 8831, 1980, 27 pp.

Rhodes, H. L. An Apparatus and Procedure for Calibrating a Water Vapor Analyzer in the 0.1- to 15-ppm Range. BuMines RI 8548, 1981, 8 pp.

Seitz, C. A., and G. M. Lucich. Automatic and Continuous Transducer-Drift Compensator for Endpoint Detection Systems. BuMines RI 8568, 1981, 9 pp.

Tongish, C. A. Helium—Its Relationship to Geologic Systems and Its Occurrence With the Natural Gases, Nitrogen, Carbon Monoxide, and Argon. BuMines RI 8444, 1980, 176 pp.

Patents[2]

Atkinson, G. B. Preparation and Use of High Surface Area Transition Metal Catalysts. U.S. Pat. 4,256,653, Mar. 17, 1981.

Atkinson, G. B., L. J. Nicks, and D. J. Bauer. High Surface Area Transition Metal Catalysts and Method of Preparing Same. U.S. Pat. 4,287,095, Sept. 1, 1981.

——— Thorium Oxide-Containing Catalyst and Method of Preparing Same. U.S. Pat. 4,301,032, Nov. 17, 1981.

Baglin, E. G., G. B. Atkinson, and L. J. Nicks. Catalyst for Synthesis of Methanol. U.S. Pat 4,181,630, Jan. 1, 1980.

[2] These processes may be used by any U.S. citizen or organization without royalty payment upon authorization by the U.S. Department of the Interior. Application for the use of any of these patents should be made to the Office of the Solicitor, U.S. Department of the Interior, Washington, D.C. 20240.

Bernard, T. E., and R. L. Stein. Self-Contained Closed Circuit Breathing Apparatus Having a Balanced Breathing Resistance System. U.S. Pat. 4,299,216, Nov. 10, 1981.

Bice, C. D., J. H. Cooper, and M. L. Fenger. Electrical Cable Coupler With Rotatable Protective Covers. U.S. Pat. 4,203,640, May 20, 1980.

Blickensderfer, R. Sputtering Apparatus for Coating Elongated Tubes and Strips. U.S. Pat. 4,290,877, Sept. 22, 1981.

Borrowman, S. R., and P. B. Altringer. Sorption of Tungsten From Alkaline Solutions. U.S. Pat. 4,241,028, Dec. 23, 1980.

Bruckenstein, S., and J. A. Kosek. Electrochemical Apparatus for Simultaneously Monitoring Two Gases. U.S. Pat. 4,315,753, Feb. 16, 1982.

Carnahan, T. G., and C. M. Flynn, Jr. Siliceous Adsorbent for Heavy Metals. U.S. Pat. 4,256,587, Mar. 17, 1981.

Cheng, L., and W. G. Cross. Portable Airborne Droplet Impactor Sampler and Method. U.S. Pat. 4,265,107, May 5, 1981.

Coby, A. D., and W. L. Cooley. Apparatus for the Continuous Monitoring of Ground Bed Resistance. U.S. Pat. 4,209,741, June 24, 1980.

Cole, E. R., Jr., A. Y. Lee, and D. L. Paulson. Electrowinning of Lead From H_2SiF_6 Solution. U.S. Pat. 4,272,340, June 9, 1981.

Colombo, A. F., and D. M. Hopstock. Process for Scavenging Iron From Tailings Produced by Flotation Beneficiation and for Increasing Iron Ore Recovery. U.S. Pat. 4,192,738, Mar. 11, 1980.

Davidson, C. F. Extraction of Metals From Mixtures of Oxides or Silicates. U.S. Pat. 4,307,066, Dec. 22, 1981.

_____. Recovery of Lithium From Low-Grade Ores. U.S. Pat. 4,285,914, Aug. 25, 1981.

Divers, E. F. Combined Rotating Bed Scrubber and Water Eliminator. U.S. Pat. 4,266,829, May 12, 1981.

_____. Mine Face Ventilation Device. U.S. Pat. 4,235,163, Nov. 25, 1980.

Divers, E. F., and J. C. LaScola. Slideboard Device for Underground Mine Face Ventilation. U.S. Pat. 4,282,802, Aug. 11, 1981.

Dressell, M. O. Automatic Feed and Rotational Speed Control System of a Hydraulic Motor Operated Drill. U.S. Pat. 4,271,914, June 9, 1981.

Droullard, R. F., and R. F. Holub. Method of Continuously Determining Radiation Working Level Exposure. U.S. Pat. 4,185,199, Jan. 22, 1980.

Dudgeon, J. E., and D. A. Stanley. System for Maintaining High Resonance During Sonic Agglomeration. U.S. Pat. 4,307,964, Dec. 29, 1981.

Dunning, B. W., Jr., and D. H. Chambers. Electrolytic Stripping Cell. U.S. Pat. 4,242,192, Dec. 30, 1980.

Eichbaum, B. R., J. A. Eisele, and D. J. Bauer. Production of Alumina From Aluminum Nitrate Solutions. U.S. Pat. 4,260,589, Apr. 7, 1981.

Eisele, J. A., D. J. Bauer, and P. R. Bremner. Removal of Impurities From Clay. U.S. Pat. 4,239,735, Dec. 16, 1980.

Fraley, J. E., E. F. Sommers, S. Strang, and W. C. McConnell. Induced Air Flow Self-Cleaning Spray Nozzle. U.S. Pat. 4,200,232, Apr. 29, 1980.

Flinn, D. R., and C. L. Manger. Process of Electroplating a Platinum-Rhodium Alloy Coating. U.S. Pat. 4,285,784, Aug. 25, 1981.

Flynn, C. M., Jr., T. G. Carnahan, and R. E. Lindstrom. Recovery of Bismuth From Chloride Process Solutions. U.S. Pat. 4,285,912, Aug. 25, 1981.

_____. Selective Removal of Mercury From Cyanide Solutions. U.S. Pat. 4,256,707, Mar. 17, 1981.

Gokcen, N. A. Method for Measuring the Ionic Activities in Water With a Differential Pressure Transducer. U.S. Pat. 4,301,676, Nov. 24, 1981.

Golben, P. M. Metal Hydride Actuation Device. U.S. Pat. 4,282,931, Aug. 11, 1981.

Gomes, J. M., D. A. O'Keefe, and R. M. McAlexander. Froth Flotation Using Lanolin Modifier. U.S. Pat. 4,208,275, June 17, 1980.

Grant, D. C., and H. A. Burgman. Permeability Restoration and Lowering of Uranium Leakage From Leached Ore Beds. U.S. Pat. 4,270,802, June 2, 1981.

Guay, P. J. Link-Loc Chainless Haulage System. U.S. Pat. 4,254,710, Mar. 10, 1981.

Guidotti, R. A. Removal of Sodium Sulfate From a Sulfate-Containing Sodium Chloride Solution in a Process for Separating Zirconium and Hafnium. U.S. Pat. 4,242,312, Dec. 30, 1980.

Gunderman, R. J., and M. W. Riley. Multilayer Pressure Vent for Explosion Proof Enclosures. U.S. Pat. 4,328,901, May 11, 1982.

Hawkes, I. Method of Anchoring a Vibrating Wire Into a Hollow Gauge Body. U.S. Pat. 4,203,192, May 20, 1980.

Heinen, H. J., G. E. McClelland, and R. E. Lindstrom. Leaching Agglomerated Gold-Silver Ores. U.S. Pat. 4,256,705, Mar. 17, 1981.

_____. Leaching Agglomerated Gold-Silver Ores. U.S. Pat. 4,256,706, Mar. 17, 1981.

Heinen, H. J., D. G. Peterson, and R. E. Lindstrom. Desorption of Gold From Activated Carbon. U.S. Pat. 4,208,378, June 17, 1980.

Hennion, E. J., J. J. deBarbadillo, and U. M. U. Ahmad. Recovery of Chromium From Scrap. U.S. Pat. 4,259,296, Mar. 31, 1981.

Henry, H. G. Separation of Zirconium and Uranium. U.S. Pat. 4,330,509, May 18, 1982.

Hermann, C., III. Extensometer Anchor. U.S. Pat. 4,242,915, Jan. 6, 1981.

Hulatt, J. L., and M. B. Shirts. Amine Flotation of Chromite From Acidic Pulps. U.S. Pat. 4,311,584, Jan. 19, 1982.

Hulatt, J. L., M. B. Shirts, and G. M. Potter. Molybdenite Flotation. U.S. Pat. 4,231,859, Nov. 4, 1980.

Jong, B. W. Process for Producing a Metastable Precursor Powder and for Producing Sialon From This Powder. U.S. Pat. 4,148,884, Jan. 22, 1980.

Khalafalla, S. E., G. W. Reimers. Method for Clarifying Slimes. U.S. Pat. 4,295,971, Oct. 20, 1981.

Khalafalla, S. E., G. W. Reimers, and S. A. Rholl. Dilution Stable Water Based Magnetic Fluids. U.S. Pat. 4,208,294, June 17, 1980.

Larson, W. C., and R. J. Morrell. In Situ Leaching Mining Method Using Branched Single Well for Input and Output. U.S. Pat. 4,222,611, Sept. 16, 1980.

Liebman, I., J. Corry, and R. Pro. Passive Explosion Barrier for Mines. U.S. Pat. 4,284,144, Aug. 18, 1981.

MacDonald, D. J. Separation of Zirconium From Hafnium by Solvent Extraction. U.S. Pat. 4,231,994, Nov. 4, 1980.

Matta, J. E., and F. N. Kissell. Ventilation System for Automated Mining Machines. U.S. Pat. 4,200,036, Apr. 29, 1980.

McBee, W. C., and T. A. Sullivan. Modified Sulfur Cement. U.S. Pat. 4,311,826, Jan. 19, 1982.

_____. Recycling Spent Asphaltic Concrete. U.S. Pat. 4,239,547, Dec. 16, 1980.

Montagna, D., and H. V. Makar. Method for Wrought and Cast Aluminum Separation. U.S. Pat. 4,330,090, May 18, 1982.

Morrell, R. J., W. C. Larson, and R. D. Schmidt. Method of In Situ Mining. U.S. Pat. 4,249,777, Feb. 10, 1981.

Moser, K. W., R. E. Siemens, and S. C. Rhoades. Recovery of Valuable Organic and Aqueous Phases From Solvent Extraction Emulsions. U.S. Pat. 4,231,866, Nov. 4, 1980.

Pahlman, J. E., and S. E. Khalafalla. Production of Ferrochromium Alloys. U.S. Pat. 4,306,905, Dec. 22, 1981.

_____. Recovery of Metals From Atlantic Sea Nodules. U.S. Pat. 4,208,379, June 17, 1980.

Paice, D. A. High Frequency Lighting Inverter With Constant Power Ballast. U.S. Pat. 4,220,896, Sept. 2, 1980.

_____. Portable Calibrator for D.C. Circuit Breakers. U.S. Pat. 4,209,739, June 24, 1980.

Paice, D. A., and A. B. Shimp. Discriminating Circuit Breaker Protection System Direct Current Power Distribution System. U.S. Pat. 4,296,450, Oct. 20, 1981.

Parry, J. M., and P. Raccah. Method of Manufacturing a Gas Sensor. U.S. Pat. 4,221,827, Sept. 9, 1980.

Retka, T. J., and D. W. Schoen. Auger Construction Providing Reduced Noise. U.S. Pat. 4,266,830, May 12, 1981.

Roepke, W. W. Dust Controlling Method Using a Coal Cutter Bit. U.S. Pat. 4,251,109, Feb. 17, 1981.

Roepke, W. W., and S. J. Anderson. Triangular-Shaped Cutting Head for Use With a Longwall Mining Machine. U.S. Pat. 4,303,277, Dec. 1, 1981.

Roepke, W. W., and R. J. Wilson. Mounting Block To Rotate Coal Cutter Bits. U.S. Pat. 4,302,053, Nov. 24, 1981.

Sainato, A., J. Cervik, and L. J. Prosser, Jr. Flexible Continuous Grout Filled Packer for Use With a Water Infusion System. U.S. Pat. 4,300,631, Nov. 17, 1981.

Sandberg, R. G., and T. L. Hebble. Recovery of Metal Values From Lead Smelter Matte by Leaching With Manganese Dioxide and Sulfuric Acid. U.S. Pat. 4,231,993, Nov. 4, 1980.

Schiller, J. E., and S. E. Khalafalla. Removal of Asbestos Fibers From Water. U.S. Pat. 4,181,607, Jan. 1, 1980.

Schultze, L. E., D. J. Bauer, and M. T. Morimoto. Ferric Leaching of Uranium Values From Lignite. U.S. Pat. 4,272,491, June 9, 1981.

Shah, I. D. Decomposition of $AlCl_3 \cdot 6H_2O$ in H_2 Atmosphere. U.S. Pat. 4,259,311, Mar. 31, 1981.

Siemens, R. E., D. N. Nilsen, and S. C. Rhoades. Process for Recovering Ni(II), Cu(II), and Co(II) From an Ammoniacal-Ammonium Sulfate Leach Liquor. U.S. Pat. 4,258,016, Mar. 24, 1981.

Smelley, A. G., R. W. Montgomery, and B. J. Hamner. Dewatering of Slimes. U.S. Pat. 4,303,532, Dec. 1, 1981.

Smith, G. E., J. L. Huiatt, and M. B. Shirts. Amine Flotation of Chromite From Acidic Pulps. U.S. Pat. 4,311,584, Jan. 19, 1982.

Soboroff, D. M., and H. O. McDonald. Copper Electrowinning and CR^{+6} Reduction in Spent Etchants Using Porous Fixed-Bed Coke Electrodes. U.S. Pat. 4,256,557, Mar. 17, 1981.

Thompson, P., J. L. Huiatt, and D. C. Seidel. Froth Flotation of Insoluble Slimes From Sylvinite Ores. U.S. Pat. 4,192,737, Mar. 11, 1980.

Tweeton, D. R. Impedance Measuring Method of and Apparatus for Detecting Escaping Leach Solution. U.S. Pat. 4,253,063, Feb. 24, 1981.

Wong, M. M., and F. P. Haver. Method of Recovering Lead Through the Direct Reduction of Lead Chloride by Aqueous Electrolysis. U.S. Pat. 4,181,588, Jan. 1, 1980.

*U.S. GOVERNMENT PRINTING OFFICE : 1982 0-384-460/220

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.